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INDEX

AUTHORS' INDEX.

SUBJECT INDEX

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THE EFFECT OF EDAPHIC CONDITIONS ON THE ECOLOGICAL ANATOMY OF CERTAIN SPECIES

BY

Parameshwar S. Gupta, M.Sc. (Lucknow), M.Sc. (Lond.)

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Introduction

Considerable amount of work has been done on the ecological anatomy of plants with relation to climatic factors, and a vast literature already exists on the subject. But comparatively little has been written concerning the influence of soil factors on anatomical structure, and this almost exclusively from the point of view of the moisture relations.

What little has been done in this direction has clearly shown that the Edaphic Factors play as great a part in modifying the structure of plants as any other environmental factors. Bonnier (2) found that *Ononis Natrix* on soils poor in calcium possesses a physiognomy different to that which it exhibits on the calcareous soils which it usually occupies. From culture experiments on the calcareous and non-calcareous soils he found that the plants possessed distinct structure on each.

Numerous observations in the field especially those of Fliche and Grandeau (3) have also demonstrated a distinct action of calcium on the structure of plants. Masclef (8) examined specimens of

Pteris aquilina which were growing side by side on calcareous and non-calcareous soils (clay), and found that in the former case the rhizomes were shorter, provided with more numerous and thicker roots, the reserve parenchyma was more feebly, and the protective tissues more strongly, developed. Hilgard (5) has made extensive observations in North America on the influence of calcium on the configuration of plants. *Quercus ferruginea* and *Q. obtusifolia* are stunted on sand and on black prairie soil, but tall and with a different ramification on calcareous soils.

Calcium carbonate therefore seems to exert important influence on the structure of plants. The calcicolous habit is interesting from many points of view which have been fully reviewed by Salisbury (10), and Anderson (1) has recently studied the water economy of the English chalk plants in some detail.

Our investigations were made on *Anthyllis vulneraria* L, and *Centaurea nemoralis,* Jord., growing on sand, calcareous sand, clay, and calcareous clay. Both *Anthyllis* and *Centaurea* had been thoroughly tested genetically by repeated selfings at the Potterne Biological Station from where the present material was obtained, and showed no trace of segregation for any characters. A full report on the transplant experiments on these species and others which are being carried out at the above station, has been published by E. M Marsden-Jones and W. B. Turrill (7) in the journal of Ecology, 1930 and 1933.

Two sets of plants were examined in each case, one after the summer of 1931 and the other after the summer of 1932. The plants for 1931 have been referred to as *Anthyllis* I or *Centaurea* I and for 1932 as *Anthyllis* II or *Centaurea* II.

2. External Morphology and Root Anatomy. Anthyllis

(a) *External Morphology.*

The plants on clay were much smaller in external appearance than those on other types of soils. The length of main roots for both sets of plants is shown in Table I.

The longest root is met with on sand (I) with a length of 25·5 cm. The mean length for 1931 on sand is 20·0, and on calcareous sand 19·7 cm., on clay the mean length is 19·8 cm. and on calcareous clay 12·7 cm. It is true the mean lengths on calcareous sand and clay are about equal, but the range on clay 17·5 to 24·5, is seen to be much wider than on calcareous sand 19·0 to 20·4. For 1932 the mean lengths of roots on calcareous sand is 19·1 cm., on calcareous clay 16·2 cm. and on clay 14·7 cm. The only root system on sand was unfortunately damaged. It will therefore be noticed that the roots tend to be longer on light coarse-textured soils as sand

TABLE I

Length of Main Roots

Sand. I	Sand. II	Calc. Sand. I	Calc. Sand. II	Clay. I	Clay. II	Calc. Clay. I	Calc. Clay. II
25·5 cm.	10·0 cm. (Incomplete)	20·4 cm.	19·1 cm.	24·5 cm.	14·7 cm.	14·4 cm.	16·2 cm.
18·5 ,,		19·8 ,,		17·5 ,,		14·0 ,,	
16·0 ,,		19·0 ,,		17·5 ,,		9·7 ,,	
Mean 20·0 cm.		19·7 cm.		19·8 cm.		12·7 cm.	

and calcareous sand in comparison with those on heavy finely textured soils as clay and calcareous clay. The lack of sufficient data in this connection is much to be regretted, but the results appear to conform with those obtained by Salisbury (11) and the present writer (4). The roots on clay and calcareous clay were found to be thicker than those on sand and calcareous sand (Table II).

TABLE II

Soil.	Area of root sq. mm. I	II	Area of xylem sq. mm. I	II	Xylem per sq. mm. excluding cortex. I	II	No. of vessels per sq. mm. excluding cortex. I	II	Average size of vessel X 100. I	II
Sand ..	1·33	2·22	0·15	0·26	0·29	0·33	304	277	0·10	0·12
Calc. Sand.	1·06	3·80	0·11	0·34	0·27	0·19	386	196	0·07	0·10
Clay ..	1·41	3·80	0·13	0·34	0·25	0·21	315	214	0·08	0·10
Calc. Clay.	1·36	0·98	0·09	0·09	0·21	0·23	568	363	0·04	0·06

(b) Root-Anatomy.

The details of the root-anatomy of *Anthyllis* for both the seasons are given in Table II above. To economise space only the averages have been shown. It should be remembered that only one root system on each soil was available in 1932 season.

The mean cross-sectional area of the roots of *Anthyllis* I as shown in Table II on clayey soils, *i.e.,* clay and calcareous clay is definitely larger than that on sandy soils, *i.e.,* sand and calcareous sand. The development of total xylem is more in roots on non-calcareous soils than on calcareous soils. The total xylem on sand is 0·15 sq. mm., on clay 0·13 sq. mm., on calcareous sand 0·11 sq. mm., and on calcareous clay 0·09 sq. mm. Calcium carbonate therefore appears to induce reduction of total xylem in the root. This fact is brought out even more clearly when we regard the relative development of xylem is relation to area of the root excluding cortex. The exclusion of the cortex from our consideration is important for any comparative purposes, since it has been found that different tissues in the root are differently affected under different soil conditions. The mean area of xylem per sq. mm. of root excluding cortex is 0·29 sq. mm. on sand, 0·25 sq. mm. on clay, 0·27 sq. mm. on calcareous sand and 0·21 sq. mm. on calcareous clay.

Turning to the numerical consideration of the vessels we find that the average number of vessels per sq. mm. of root excluding cortex is 304 on sand, 315 on clay, 568 on calcareous clay and 368 on calcareous sand. Noticeable differences are also observed in the size of the lumen of the vessels on different soils. The lumen* of the vessels on sand is 0·10 sq. mm., on clay 0·08 sq. mm., on calcareous sand 0·07 sq. mm., and on calcareous clay 0·04 sq. mm. It would appear then that whereas the total xylem is reduced, the number of vessels is increased and the size of the lumen decreased on calcareous soils as compared with the non-calcareous soils. Since the conducting efficiency of xylem of the root with comparatively more total xylem and bigger lumen of the vessels is bound to be better than that with less total xylem and smaller lumen of the vessels, it would appear that calcareous conditions induce a decreased conducting efficiency in the roots of the plants. (Plate I.)

In general the above remarks hold good for *Anthyllis* II also but caution must be exercised when comparing them as only single root systems were available on each soil.

3. Area of Assimilatory Organs.
Anthyllis I and II

The mean areas of leaves for both the seasons are given in Table III together with the water-capacity and water content of the soils on which the plants were growing.

Comparing the same category of soil as for instance clay with calcareous clay and sand with calcareous sand, a direct correlation between the area of the leaves and the water content or water-capacity of the soils is noticeable. Higher the water content, bigger the leaf

* Area of lumen has been referred to here and subsequently as the actual area magnified 100 times.

area. The relationships between the leaf areas of plants on calcareous sand and calcareous clay are maintained during both the seasons, calcareous clay having produced smaller leaves despite its higher water content as compared with calcareous sand. The modifications

TABLE III

Area of Assimilatory Organs—*Anthyllis* I and II

Soil.	Water capacity. %	Water content. %	Area of leaves. Sq. cm.		Xylem per sq. mm. in root.		Average size of the vessel.	
—	—	—	I	II	1931	1932	1931	1932
Clay ..	62·10	35·20	3·10	9·30	0·25	0·21	0·08	0·10
Calc. Clay. ..	54·05	32·30	1·84	5·59	0·21	0·23	0·04	0·06
Calc. Sand. ..	30·80	11·60	5·22	8·75	0·27	0·19	0·07	0·10
Sand ..	26·00	9·90	4·94	7·39	0·29	0·33	0·10	0·12

in the morphology of the root and in its internal anatomy seem responsible for this. The roots on calcareous clay are smaller (Table I) and their conduction efficiency, as judged by the amount of xylem and the size of the bore of the vessels, lower than that on calcareous sand, and this appears to offset the higher water content of calcareous clay in producing bigger leaves. Further evidence in this connection is forthcoming when the leaf areas are compared on clay and calcareous sand. It is found that in 1931 when the plants on clay have less xylem in the root than calcareous sand the area of the leaves is smaller on the former soil, but in 1932 clay possesses more xylem than calcareous sand and the area of the leaves is also larger. The same is true between sand and clay in 1931 but not in 1932. So that in general it would appear that the area of the leaves is closely related to the water content of the soil on which the plants are growing, the higher the available water, the larger the assimilatory surface.

4. Leaf Anatomy

All observations were made on comparable sections cut from the middle region of the leaves. In every case ten to fifteen leaves were examined. Owing to the habit of *Centaurea* and *Anthyllis* the question of the position of the leaves on the stem did not arise. In Table IV are out the mean values only.

Both in *Centaurea* and *Anthyllis* the leaves are thickest on sand, intermediate on calcareous sand and calcareous clay, and thinnest on clay. The upper epidermis is thickest on sand, thicker on sand than on calcareous sand, thicker on calcareous clay than on clay (*Centaurea*). In *Anthyllis* also it is thickest on sand, thicker on sand than on calcareous sand, but thicker on clay than on calcareous clay. In *Centaurea* the leaves have the lower epidermis thickest on sand, it is thicker on sand than on calcareous sand, thicker on calcareous clay than on clay. But in *Anthyllis* the lower epidermis is thicker on calcareous soils as compared with the non-calcareous soils. Both in *Centaurea* and *Anthyllis* the development of palisade tissue is greater on sand than on calcareous sand, and on calcareous clay as compared with clay. In *Centaurea* more spongy tissue is developed on calcareous sand than on sand, and on clay than on calcareous clay. In *Anthyllis* more spongy tissue is developed on calcareous sand than on sand as in *Centaurea,* but more development of this tissue is found on calcareous clay than on clay.

TABLE IV
Details of Leaf Anatomy. (Mean)

	Anthyllis II.				Centaurea I.			
	Sand.	Calc. sand.	Calc. clay.	Clay.	Sand.	Calc. sand.	Calc. clay.	Clay.
Thickness of leaf (T). mm. ..	0·430	0·391	0·368	0·338	0·219	0·213	0·211	0·193
Upper Epidermis. mm. ..	0·032	0·029	0·027	0·029	0·023	0·021	0·021	0·020
Lower Epidermis. mm. ..	0·031	0·033	0·033	0·029	0·019	0·018	0·019	0·018
Palisade (P). mm. ..	0·194	0·164	0·147	0·139	0·081	0·074	0·075	0·068
Spongy (S). mm. ..	0·172	0·172	0·160	0·140	0·095	0·098	0·095	0·086
$\frac{T}{P}$ ..	2·22	2·46	2·51	2·46	2·72	2·86	2·79	2·83
$\frac{P}{S}$ ..	1·12	0·95	0·98	1·01	0·84	0·75	0·81	0·80

The structure of leaves of *Centaurea* and *Anthyllis* is therefore appreciably modified by different soil types. Plants growing on sand show a typically xerophytic structure in possessing thicker leaves, thicker epidermis, better development of the palisade, and weakly developed spongy tissues. The leaves on clay on the other hand

display a more or less mesophytic structure. Leaves are comparatively thinner, less palisade development, epidermis thinner, and spongy tissue better developed. The leaves on calcareous sand are less xerophytic when compared with sand and those on calcareous clay more xerophytic when compared with clay.

On account of the peculiar physical and chemical properties of the calcareous soils both *Centaurea* and *Anthyllis* modify their structure. Despite however the tendency of similar edaphic factors to exercise similar structural response in both, the habit of the plants may be a more important factor in deciding the degree of such response.

5. Stomatal Frequency and Stomatal Index

(a) *Anthyllis.*

Anthyllis vulneraria is characterised by having a higher stomatal frequency on the upper than on the lower side of the leaf. All the determinations were made from corresponding areas of the middle region of the leaf, so as to render comparison valid (cf. Salisbury 12). Because of the tufted habit of *Anthyllis* the question of the position of the leaf on the stem did not present much difficulty; as far as possible the leaves were selected from the same position in the tuft.

The stomatal frequency is calculated for an area of 1 sq. mm., and the stomatal index has been calculated from Salisbury's formula

$$\frac{S}{E + S} \times 100$$

The stomatal frequency and the stomatal index of *Anthyllis* (1931) for the upper and the lower surfaces are set out in Table V.

It will be seen from the above table that plants on clay give the highest stomatal frequency for both the surfaces, and sand and calcareous sand the lowest. Taking the texture of the soil into consideration it should have been otherwise. We shall have occasion to enquire into this later on. The difference between the mean indices for the upper surface is only 3·2, and that for the lower surface 1·8, and are therefore regarded as fairly constant for both the surfaces.

Salisbury (12) has shown a marked correlation in a number of cases between the number of epidermal cells and the stomatal-frequency in the same area. The correlation co-efficient for *Anthyllis* I on sand is $+\cdot 8213$, with a probable error of $\cdot 0490$, on calcareous sand $+\cdot 5216$ with a probable error of $\cdot 1097$, on clay $+\cdot 5529$ with a probable error of $\cdot 1046$, and on calcareous clay $+\cdot 8596$ with a probable error of $\cdot 0392$, we see here therefore that the correlation is of a very high order.

To check the results obtained above, the observations were repeated on a different set of *Anthyllis* plants in October of

1932, and it was discovered that these plants show a distinct difference in the proportion of stomata formed to those formed in 1931. This suggested the possibility of climatic factors as playing some part in affecting the stomatal index, and hence this enquiry was pushed further.

TABLE V

Stomatal Frequency and Stomatal Index (Mean) (20—25 Leaves Examined in each Case)

	Anthyllis I.				Anthyllis II.			
	Sand.	Calc. Sand.	Clay.	Calc. Clay.	Sand.	Calc. Sand.	Clay.	Calc. Clay.
Stomatal Frequency—								
Upper.	142·8	178·1	200·3	175·2	144·7	137·3	139·9	161·0
Lower.	85·2	76·6	98·7	79·6	84·4	77·7	72·7	96·5
No. of Epidermal Cells per unit area—								
Upper.	414·6	444·1	572·4	526·8	301·9	298·1	301·0	373·7
Lower.	349·7	281·4	374·6	302·7	257·1	266·7	259·6	300·5
Stomatal Index—								
Upper.	25·8	28·6	26·3	25·4	30·9	31·6	31·8	30·3
Lower.	19·3	21·3	20·8	20·6	25·3	22·2	21·7	24·4

The stomatal frequency and the stomatal index for *Anthyllis* II is also shown in Table V above. Comparison of the two extreme soils such as sand and clay gives a higher frequency for plants on the former soil which is a coarse textured soil, and a low frequency for the latter which is a finer textured soil. The stomatal indices for both the surfaces are again found to be fairly constant as the differences between the upper surface and the lower are only 1·5 and 3·5 respectively. The correlation co-efficient between the number of stomata and the number of epidermal cells in 1 sq. mm. for plants on sand is +·9312 with a probable error of ·0249, on calcareous sand + ·7553 with a probable error of ·0647, on clay +·8941 with a probable error of ·0301, and on calcareous clay +·9644 with a probable error of ·0105, a very marked correlation indeed.

Despite the fact that Salisbury has shown that a species tends to form a characteristic proportion of stomata which is hardly influenced by environment, my results as outlined in Table V indicate quite clearly that *Anthyllis* shows a lower index in respect to both the surfaces in 1931 as compared with 1932. The mean index for all the soils in 1931 is 26·52 for the upper and 20·52 for the lower surface, in 1932 it is 31·15 for the upper and 23·49 for the lower surface. It has also been pointed out above that the index

is approximately constant for either year on different soils. So, that though different soils give a more or less constant index for either year, or in other words an approximately equal proportion of stomata has been formed by the plant on different soils, the climatic factors exercise a very important and significant influence on the proportion of stomata formed even within the same species from one season to another. The uniform increase of index (means as well as the ranges) on each soil type from 1931 to 1932 supplies further evidence in that connection.

In so far as stomatal index may be regarded as an indicator of favourable or unfavourable moisture relations of the plants with its environment, the rainfall data for the two seasons, kindly supplied by Mr. Marsden-Jones (from April to September each year), giving 447·20 mm. of rainfall for 1931 and 432·50 mm. for 1932, indicates that under the comparatively wet conditions of 1931 a lower proportion of stomata has been formed as compared with the drier conditions of 1932. The specific character of the index is not altered however from one season to another and thus confirms Salisbury's original suggestion. The differences in the indices as noted above lie well within the normal range of variation for the species, only that the model value for the proportion of the stomata

Stomatal Index (Upper Surface)

	1931.		1932.	
	Mean.	Range.	Mean.	Range.
Sand ..	25.8	22·4—28·5	30·9	28·8—38·1
Calc. Sand ..	28·6	25·7—34·2	31·6	28·5—36·2
Clay ..	26·3	23·3—28·4	31·8	27·8—34·2
Calc. Clay ..	25·6	21·6—30·1	30·3	27·0—32·6

formed has been slightly shifted towards the right in 1932 as a response to drier season.

(b) Centaurea.

The frequencies and indices of *Centaurea* I and II for the upper as well as the lower surfaces are given in Table VI. It will be observed from the following tables that unlike *Anthyllis, Centaurea* gives a higher frequency on light coarse textured soil such as sand and a lower frequency on fine textured soil as clay and calcareous

clay. It was noticed in the case of *Anthyllis* I that plants on clay gave the highest stomatal frequency and those on sand the lowest for both the surfaces, and in *Anthyllis* II, those on calcareous clay gave the highest frequency and on calcareous sand the lowest. But *Centaurea* in both the seasons gives the highest frequency on sand and lowest on calcareous clay or clay.

TABLE VI

Stomatal Frequency and Stomatal Index (Mean) (20-25 Leaves examined in each case)

	Centaurea I.				Centaurea II.			
	Sand	Calc. Sand	Clay	Calc. Clay	Sand	Clac. Sand	Clay	Calc. Clay
Stomatal Frequency—								
Upper	29·9	27·2	24·2	24·2	37·1	33·8	28·1	32·5
Lower	124·7	106·6	96·5	95·2	133·1	114·0	113·9	109·0
No. of Epidermal Cells per unit area—								
Upper	470·6	486·7	489·8	460·9	504·1	460·7	350·2	475·3
Lower	634·2	601·4	570·5	581·3	628·2	526·1	547·3	560·4
Stomatal Index—								
Upper	5·9	5·2	4·6	4·9	7·1	6·8	7·5	6·4
Lower	16·5	15·0	14·5	14·1	17·5	17·8	17·2	16·3

So that we can say that whereas *Centaurea* gives the sequence as expected, in *Anthyllis* the rule is departed from. The explanation of this behaviour may be sought in the fact that *Anthyllis vulneraria* is a shallow rooted species and *Centaurea nemoralis* a deep rooted one. Since roots superficially placed are subjected to maximum climatic changes as compared with those experienced by more deeply situated ones, and the conditions in the deeper layers being more equable, the differences in the behaviour of these species may be accounted for.

Centaurea like *Anthyllis* gives an approximately constant stomatal index for both surfaces in both the years. The correlation co-efficient for the two years was also quite significant.

Centaurea like *Anthyllis* gives a somewhat lower index in 1931 than in 1932 in respect to both the surfaces, at the same time the specific character of the index is not lost. Nevertheless when we consider not only the means but the ranges of the index observed on each soil type it is evident that the uniform increase in the number of stomata formed cannot be attributed to chance, and this taken in conjunction with the results obtained with *Anthyllis* points

clearly to climatic factors as important in influencing the number of stomata formed.

Lower Surface

—	1931		1932	
—	Mean Index	Range	Mean Index	Range
Sand ..	16·5	13·4—19·8	17·5	13·3—19·2
Calc. Sand ..	15·0	13·3—16·3	17·8	15·9—19·6
Clay ..	14·5	12·4—16·7	17·2	16·0—20·3
Calc. Clay ..	14·1	9·3—16·4	16·3	12·6—18·7

The stomatal frequencies of *Anthyllis* and *Centaurea* have been plotted in Fig. 2, against the water-capacity and water content of the soils, and the following Table has been drawn up to show the relation of stomatal frequency and water content of the soil, and the amount of xylem in the root and the size of the vessels, *i.e.*, the conducting efficiency of the root, for *Anthyllis* I. The figure clearly shows that in *Centaurea* a high frequency is associated with low water capacity of the soil, in other words with a coarse textured soil like sand, but in *Anthyllis* it varies directly as the water capacity of the soils, and inversely as the amount of xylem and the size of the bore of the vessels. So that the effect of the texture of the soil

Anthyllis I

Soil.	Total St. Fr.	Xylem per sq. mm. of root.	Lumen of the vessel X 100.	Water Capacity %	Water Content %
Sand ..	228·0	0·296	0·10	26·0	9·9
Calc. Sand ..	254·7	0·270	0·07	30·8	11·6
Calc. Clay ..	254·8	0·215	0·04	54·0	32·3
Clay ..	299·0	0·250	0·08	62·0	35·2

on the stomatal frequency is counteracted upon by the conducting efficiency of the root.

Anthyllis in 1932 behaved like *Centaurea* on all soils except calcareous clay, and the writer is inclined to regard this as a case

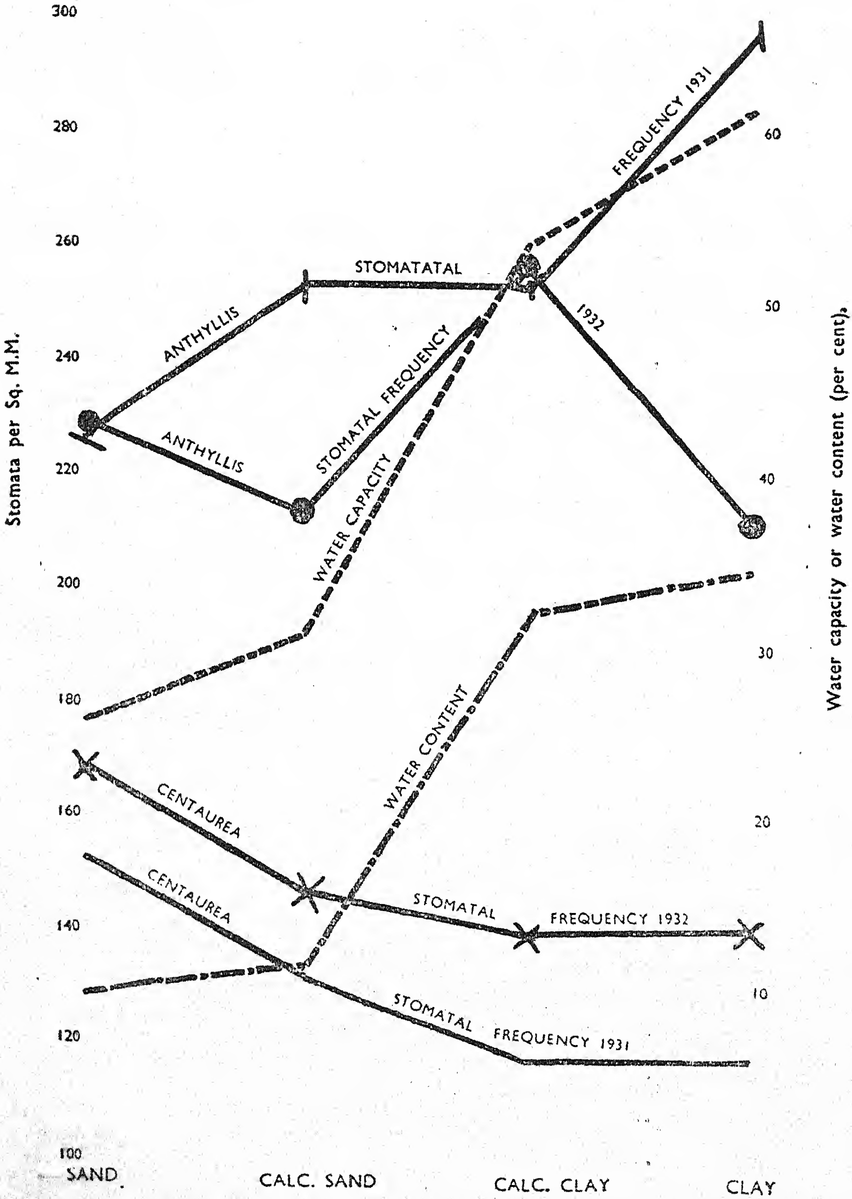

Fig. 2.—Correlation of Stomatal frequency and water capacity and water content of the soils.

of local adjustment of water supply to the plants by the modification of the external morphology and internal anatomy of the absorbing organs.

It would therefore appear that the conducting efficiency of the vessels in the roots and the extent of the roots of the plants growing on soils of different texture may well compensate for the effect of the texture of the soil on the stomatal frequency. Actually then these results instead of casting doubt on the efficiency of the stomatal frequency as an index of moisture conditions tend rather to confirm its value as safeguarding us from assumptions based on too narrow an apriori condition.

6. General Discussion

The studies into the effect of different soil types on the structure of *Centaurea* and *Anthyllis* in the preceding pages have elucidated certain important points which must be brought together for a proper understanding of the significance of these results. It should be noticed from the analyses of the soils given below that the main differences in the soils are those of texture apart from the presence of a high percentage of calcium carbonate in the

TABLE VII

Analyses of the Soils

	Sand (% gm.)	Calc. Sand (% gm.)	Clay (% gm.)	Calc. Clay (% gm.)
P_2O_5 (total) ..	0·1164	0·1548	0·0446	0·1575
K_2O (total) ..	0·0868	0·1548	0·5464	0·1554
P_2O_5 (available) ..	0·0021	0·007	0·0116	Unable to estimate because of too much $CaCO_3$
K_2O (available) ..	0·0071	0·0342	0·0371	
$CaCO_3$ ..	*nil*	9·5	0·36	52·22
Nitrogen ..	0·0437	0·0235	0·1235	0·0168
Ph (as Collected) ..	7·33	8·3	7·37	8·58
Ph (air dried) ..	6·5	7·96	7·12	8·02

calcareous soils and in particular in the calcareous clay. The nutrients are more or less equal in all the soils. Consequent

upon the differences in the texture of the soils the water holding capacity of the soils is very different, which is for sand 26%, for calcareous sand 30·8%, for calcareous clay 54·05%, and for clay 62·1%.

The distinctions introduced into the properties of clay and sand by the presence of calcium carbonate should however be recognised. As might be expected at first calcium carbonate does not bring about the same changes in the properties of clay and sand when present in them. The action of calcium carbonate on different soils depends upon a number of factors of which the texture of the soil is not the least important. These have been fully discussed by Russell (9), and need not detain us much longer than to consider the most important from our point of view. One of the main results of the presence of any appreciable quantity of calcium carbonate in any soil is the change in its reaction. The soil becomes basic. Calcareous soils are supposed to be very favourable environments for the development of extensive root systems, and hence the plants are equipped with organs for a better absorption of water from the soil.

The physical changes brought about in the constitution of the soil by the presence of calcium carbonate are also very important, on the one hand it flocculates the colloids in the clay, thus affecting the texture of the soil making it less retentive of water and improving the drainage, on the other, as my quantitative determinations have shown, calcium carbonate increases the water holding capacity of sand, how this is brought about I am unable to explain at present. One important difference between calcareous clay and calcareous sand is at once noticeable, the water holding capacity of clay is lowered and that of sand raised by the presence of calcium carbonate. Since the basic reaction of the soil as we have seen favours the absorption of water from the calcareous sand, this together with the high water holding capacity as compared with sand, introduces important differences in the structure of plants growing on those soils. The state of affairs is slightly different in calcareous clay and clay. On the one hand the absorption of water is improved on calcareous clay as compared with clay, on the other, calcareous clay loses more water than clay on account of its texture. This loss of water may be considerable by evaporation and percolation as shown by Baldwin Latham (6), and it is therefore clear why plants on calcareous clay have a comparatively bigger root system associated with feebly developed above ground organs, and a more xerophytic structure as compared with clay.

We can now return to the consideration of the assimilatory organs of *Anthyllis*. The leaves of *Anthyllis* on sand are smaller than those on calcareous sand, and those on calcareous clay smaller as compared with those on clay. In the light of above arguments with regard to the texture of the soil it would appear that the area of the leaves corresponds with conditions in the different soils. It

is enough to recall here that the effect of the texture of the soil on the area of the leaves may be masked by the morphology and anatomy of the underground organs found in those soils.

Corresponding with the leaf area, plants on sand show a different anatomical structure compared with those on calcareous sand, and those on calcareous clay different to those on clay. Both *Anthyllis* and *Centaurea* give a higher stomatal frequency, thicker leaves, thicker upper and lower epidermis, more relative development of palisade tissue, and less spongy tissue in plants on sand than those on calcareous sand and those on calcareous clay than on clay. All these characters are of typical xerophytes, or in other words taking the same category of soil, *i.e.,* clay or sand, plants tend to be more xerophytic on sand than on calcareous sand, and more xerophytic on calcareous clay than on clay.

Since plants within the same category of soil show distinct structure, it is scarcely surprising that this is true also of plants on different categories of soils, as for instance those on sandy soil including sand and calcareous sand, and clayey soil including clay and calcareous clay. In *Centaurea* as well as *Anthyllis* it is found that plants on sandy soils are more xerophytic than those on clayey soils. This is more prominent in the former case than in the latter, and this may well be due to *Centaurea nemoralis* being a deep rooted species and *Anthyllis vulneraria* a shallow rooted one. As the conditions in the deeper layers are more equable the difference in behaviour can be explained.

And finally the importance of the climatic factors in influencing the number and proportion of stomata formed has been revealed in these studies. Both the species give an approximately constant index on different soils in both the seasons, but the mean index in 1932 in both is slightly higher than that in 1931, the differences being probably within the normal range of variation. Since the growing period for these plants was drier in 1932 than in 1931 the importance of the climatic factors in affecting the proportion of stomata formed should be noticed. This has been discussed at some length in connection with the two species elsewhere.

Summary

The effect of different soil types such as sand, calcareous sand, clay and calcareous clay has been studied on the structure of *Anthyllis vulneraria* and *Centaurea nemoralis*. That the differences in the soils were mainly due to the texture was shown by the analyses of the soils. In general plants on light coarse textured soils such as sand give a higher stomatal frequency than those on heavy finely textured soils as clay and calcareous clay. In *Anthyllis* this rule has been departed from in some cases, and on examination of the root anatomy interesting facts have been revealed. It has been discovered that the morphological and anatomical

differences in the root tend to compensate for the texture of the soil. Despite a higher water capacity of calcareous clay the roots of the plants on that soil have comparatively less xylem and the smallest bore of the vessels, *i.e.*, lower conducting efficiency, as compared with those on sand or calcareous sand.

The proportion of stomata formed has been shown to be approximately constant on different soils. Not only the proportion of stomata formed is constant on different soils, but it is fairly constant from season to season for the particular species. It has also been brought out that in a particular season a species tends to form a definite proportion of stomata, and the difference between the proportion of stomata range of variation is still quite significant, and therefore suggests an important influence of climatic factors on the proportion of stomata formed even within the same species.

The studies into the leaf anatomy of both the species bring out the fact that the structure of the leaves follows closely the texture of the soil. This is true within the same category of soil, as sand or calcareous sand on the one hand, and clay and calcareous clay on the other, and also when comparing different categories of soils as sandy soils and clayey soils.

And finally the root anatomy of *Anthyllis* has been investigated which shows that roots are considerably modified both morphologically and anatomically on different soils. The roots on calcareous soils develop less xylem with smaller lumen of the vessels, but greater in number as compared with those on non-calcareous soils. The importance of the root anatomy in compensating the effect of soil texture on the stomatal frequency and the area of the assimilatory organs has been mentioned above.

These results therefore show that differences in edaphic conditions may be accompanied by considerable anatomical distinctions.

In conclusion I wish to express my gratefulness to Prof. E. J. Salisbury, D. SC., F. R. S., who very kindly put me on to these studies, and took a keen interest throughout the progress of the work, and provided all the facilities at the Botany Department, University College, London.

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Explanation of Plate I

Anthyllis vulneraria. Cross section of roots from comparable regions on different soils. A. Sand, B. Calcareous sand, C. Clay and D. Calcareous clay. X45.

THE DEVELOPMENT OF THE EMBRYO-SAC AND EMBRYO IN *CROTALARIA JUNCEA* L.

BY

KALI KINKAR SAMAL, M.SC.

Department of Botany, Calcutta University

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The study of the female gametophyte in Leguminosae began towards the end of the nineteenth century. A general review of the subject has been given by Schnarf (9) and recently by Roy (8) and need not be repeated here again.

Work on the embryology in this family is very meagre. Guignard (3) and Souèges (10) appear to be the only investigators who have studied the subject systematically. Souèges (10) worked on *Medicago lupulina, Trifolium minus*, and *Lotus corniculatus*. He found considerable variation in the development of the proembryo and the suspensor. Cook (2) studied the development of seed in *Crotalaria sagittalis*. He has described a few stages in the development of the embryo of that plant. Other workers have contributed very little to the subject and their work appears to be rather meagre.

Material and Methods

Plants for this investigation were grown in the University College experimental garden, and flower buds and ovaries of various ages were fixed in the field on bright sunny days. Fixation between 12 noon and 4 p.m. gave best results. To facilitate the penetration of the fixing fluid, the flowers were trimmed and hairs from the older ovaries scraped off. An exhaust pump was used at the time of fixation. A number of fixing fluids were tried of which Allen's modified Bouin's fluid gave the best result. The material was dehydrated, cleared and infiltrated in the usual way. Sections were cut 8 to 16 microns thick, depending on the stage required for study. Heidenhain's iron alum hæmatoxylin and Newton's gentian violet iodine were used for staining.

The Ovule

The ovules are arranged in two rows on the marginal placenta of the monocarpellary ovary. They vary in number; generally between 10 and 16 are noted. They are crowded together on the

placenta and apparently lie side by side in the young condition, but very soon with the growth of the carpels they become separated.

The ovule initials arise as outgrowths of the placenta, consisting of a group of homogeneous cells. The archesporium differentiates in the third layer of the nucellus as a polygonal cell of larger dimensions, with denser cytoplasm and relatively large nucleus (Plate II, Fig. 1). It either functions directly as a megaspore mother cell or cuts off a parietal cell by an oblique wall before doing so (Plate II, Fig. 3).

The megaspore mother cell undergoes a period of rest during which it is pushed inward by periclinal divisions of the overlying cells of the nucellus, with the result that during the heterotypic prophase it is found in the fourth or the fifth layer of the nucellus.

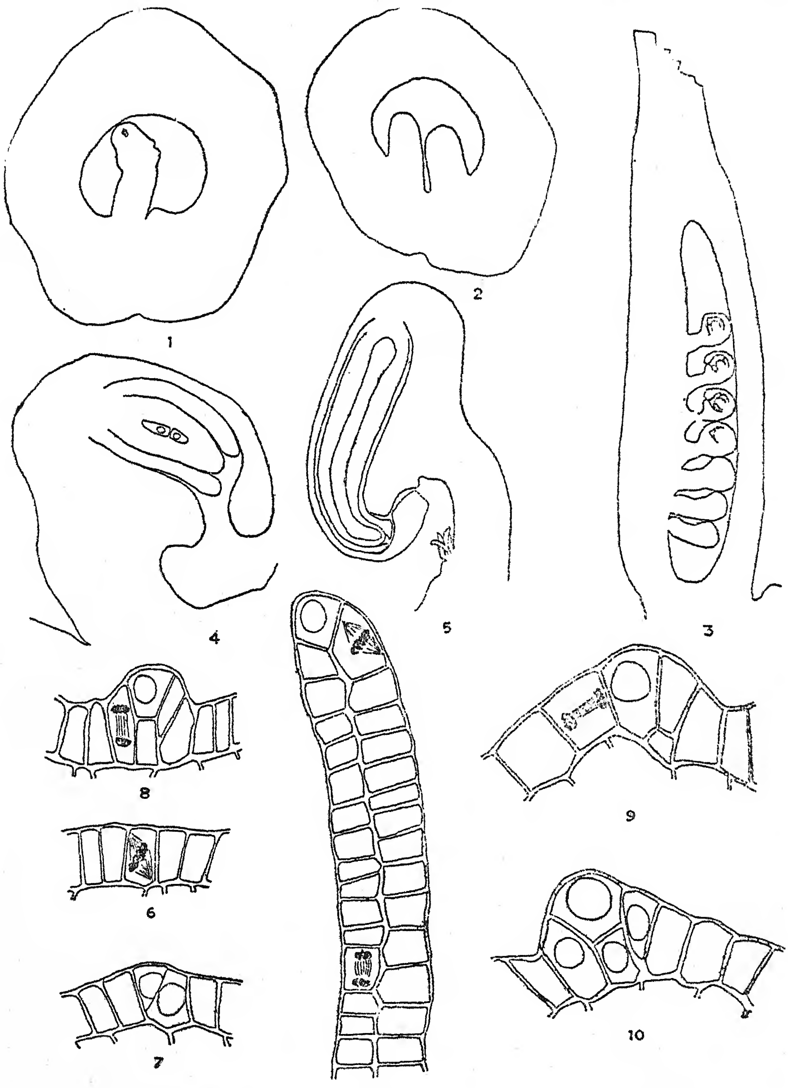
The Integuments

Simultaneously with the differentiation of the archesporial cell, the primordia of the integuments arise as annular rings at the base of the nucellus in acropetal succession. They arise exogenously and only the epidermis of the nucellus takes part in their formation. A layer of cells of the epidermis divides by oblique walls instead of radial walls. A triangular wedge-shaped cell is cut off and other adjacent epidermal cells divide radially to help in the local increase of the cell mass. The cells surrounding the wedge-shaped cell divide later by transverse walls, resulting in an integument two cells thick. The inner integument always contains only two layers of cells but the outer one is composed of more than two layers of cells especially near the micropyle.

The growth of the inner integument is more or less uniform but that of the outer is not so, the growth of the dorsal half being many times more vigorous than the ventral, and even more than the inner integument. The growth of the outer integument which is initiated later is comparatively rapid, and during the time the ovule passes from the amphitropous to the anatropous condition it overtakes the inner integument. It is really the outer integument and not the inner that covers the nucellus and forms the micropyle. The micropyle is not straight but zig-zag, since the orifice of the inner integument is not coincident with the orifice of the outer integument. (Text-fig. 5.) Reeves (7) noted a similar condition in *Medicago sativa* and Maheshwari (6) in *Albizzia Lebbek*. Roy (8) has observed similar phenomenon in a number of other leguminous plants.

The curvature of the ovule which brings about the anatropous condition is due to the vigorous growth of the cells between the hilum and the chalaza and this region subsequently forms a conspicuous raphe. The actual cause of curvature is believed to

be due to the interference of the carpellary wall. The young orthotropous ovule begins to curve when it comes in contact with the dorsal wall of the ovary. The curvature is accentuated by



Figs. 1 to 11. *Crotalaria juncea* L.

Figs. 1 and 2. The origin of the ovules and the integuments. × 75. Fig. 3. Longitudinal section of the ovary showing the arrangement of the ovules. × 30. Fig. 4. The comparative positions of the integuments in the dyad stage. × 150. Fig. 5. The position of the integuments in the mature ovule; note the unicellular hairs at the base of the funiculus. × 47. Fig. 6-11. Stages in the development of the outer integuments. × 750.

the difference in growth of the two sides of the outer integument. The orientation of the ovule later is due to the development of the raphe. When they are fully developed they make an angle of nearly 30° with the long axis of the carpel. It is difficult to state the cause of the upward curvature of the ovule. Reeves (7) found that in *Medicago sativa* the normal curvature of the ovules is downwards towards the base of the ovary, but he also found a few aberrant forms. He was of opinion that the mechanical interference exerted by the carpellary wall probably brought the curvature.

Megasporogenesis

In the resting stage of the megaspore mother cell the nucleus contains one conspicuous nucleolus, somewhat embedded is the chromatin network. After a period of rest the nucleus passes through synizetic and diakinetic stages before proceeding on to the reduction division (Plate II, Fig. 5). On the completion of the reduction division a cell plate is formed in the central region. There is a well-defined interphase with the two daughter nuclei well organised (Plate II, Fig. 6). Sometimes the lower cell of the dyad is slightly larger than the upper. The second division that follows is generally simultaneous in both the cells (Plate II, Fig 7). Sometimes, however, the chalazal cell has been observed to divide a little later. The homotypic spindles neither lie parallel to the long axis of the ovule nor at right angles to each other, but the spindle of the upper cell lies somewhat obliquely resulting in an oblique "T" shaped tetrad. The four megaspores thus formed, though similarly organised, differ greatly in shape and size (Plate II, Fig 9). The two uppermost megaspores are the smallest, the middle one intermediate, and the lowest (*i.e.*, the chalazal one), the largest of all. The three micropylar megaspores show contraction followed by degeneration and the innermost or the chalazal one functions. The upper three megaspores are gradually replaced by dark shapeless masses capping the functional megaspore.

The functional megaspore increases in size. It is pointed at the base and broad at the apex (Plate III, Fig. 10). It does not divide until it has increased to nearly ten times its volume, and pushes the adjacent cells of the nucellus which degenerate. The megaspore is vacuolated and the nucleus appears to be suspended in the centre by protoplasmic strands from the periphery. The enormous size and the vacuolisation of the megaspore, together with the amount of degeneration of the peripheral nucellar tissue, suggest that the megaspore rests for a long time before commencing activity.

Female Gametophyte

The nucleus of the enlarged megaspore divides into two daughter nuclei near the centre of the sac, and the cytoplasm is mostly aggregated in these regions. After division the nuclei

move towards the poles, being interconnected by the peripheral cytoplasm (Plate III, Fig. 11). A big central vacuole is noted at this stage and probably owes its origin to the coalescence of many smaller ones noted previously. The two nuclei at the two poles divide into four daughter nuclei, and these again divide simultaneously to form the eight-nucleate stage of the mature embryo-sac, four nuclei occurring at each pole (Plate III, Figs. 13 and 14).

Long before the organisation of the egg-apparatus and the antipodals one nucleus from each pole migrates towards the centre of the embryo-sac and the two come to lie side by side. The process of fusion of the nuclei is very slow (Plate III, Figs. 18, 19). Eight nucleate stage of the embryo-sac with two polars lying side by side is found two or three days before anthesis. In flowers fixed two or three days after anthesis, the polars have been found to have fused. After fusion the secondary nucleus of the embryo-sac increases in size three or four times and the nucleoplasm differentiates into hyaloplasm and reticulum.

While the fusion of the polar nuclei is in progress, considerable changes take place in the embryo-sac. It increases to many times its original volume and crushes the surrounding nucellar tissue. It now comes in contact with the cells of the integument. At this stage the nucellar cells appear mostly to be bi-nucleate. No special tapetal layer is noted. The chief method of obtaining nutritive supplies for the embryo-sac is by the digestion and absorption of the nucellar tissue.

The form of the embryo-sac is not cylindrical but its micropylar end is bent towards the stalk of the ovule. The three antipodal cells are practically cut off from the embryo-sac, having been forced into the wedge shaped groove at the base, in which position they disorganise along with the tubular portion of the sac before fertilization, and the embryo-sac becomes rounded at the chalazal end. Reeves (7) found in *Medicago sativa* a partial disorganisation of the chalazal groove of the embryo-sac with the antipodals. The early disorganisation of the antipodals before fertilization agrees with the general statement of Guignard (3) that the antipodals persist for a long time in the Mimosoideæ and Cæsalpinioideæ but they disintegrate earlier in Papilionatæ.

The central part of the embryo-sac is occupied by a large vacuole which pushes the cytoplasm along the side of the embryo-sac with the definitive nucleus suspended in it. The egg-apparatus at the micropylar end of the sac consists of two pyriform synergids and the egg. The egg is usually elongated and hangs down beyond the synergids (Plate III, Fig. 15). Both the synergids and the egg are vacuolated. No filiform apparatus of the synergids has been noted.

Plants grown as a *rabi* (cold weather) crop show the maturity of only a few ovules and many are seen to be abortive. One of the causes of this abortion may be accounted for as being due to the degeneration of the functional megaspore.

Pollen Tube Growth

The pollen tube in its passage through the style passes either through the conducting cells or through the stylar canal. On reaching the ovary the pollen tubes bend and grow along the ventral suture of the ovary on which the ovules are borne. Thereafter the pollen tubes turn towards the ovarian cavity forcing their way through the hairs at the base of the ovule stalks. They are difficult to distinguish from these hairs which also occur at the carpel apices. The hairs are unicellular and develop long before anthesis. Cook (2) found them to be numerous and mistook them for pollen tubes. The pollen tube travels from the base of the ovule to the micropyle in the open space of the ovarian cavity. It then enters through the zigzag orifice of the ovule (micropyle) and passes through the single layer of nucellar cells above the egg-apparatus. More than one pollen tube have been observed to enter the micropyle at a time, but not more than one was seen in contact with the egg. The pollen tube lies adpressed to the wall of the egg and often causes one of the synergids to disorganise. The other synergid often persists for a long time, but in some preparations both the synergids were found intact even after fertilization. Remnants of the pollen tubes are seen long after fertilization, but in no case they are seen to elongate beyond the egg-apparatus. Neither the union of the sperm with the egg nor triple fusion was observed.

Degeneration of Ovules

It has already been mentioned that the number of ovules in a pod is much less when plants are grown in offseason (December-February). Degeneration of the egg-apparatus at this time was found in flowers seven days old, while flowers five days old showed normal egg apparatus with no evidence of pollen tubes or sperms near by. Though insects were found visiting the flowers, yet to be certain that lack of pollination was not the limiting factor, a number of flowers were hand pollinated and the styles and ovaries were fixed 72 hours afterwards. It was noted that the pollen tube traversed nearly one-third of the stylar length by that time. It is assumed that it will take nearly 9 days for the pollen tube to reach the micropyle if it travels at this rate and so fertilization cannot take place, because the egg apparatus normally degenerates 7 days after anthesis. Besides this, it has been noted that generally between 5 and 6 days after anthesis the stigma and the style wither and if the pollen tube fails to reach the micropyle before this time, fertilization is out of the question. Thus in any case, the cause of degeneration of the ovules lies in the slow rate of pollen tube growth.

In order to note whether this slow rate of pollen tube growth was characteristic of plants grown in offseason, a number of pollen grains were germinated artificially in 2 per cent. cane-sugar solution. During the season (1933) the pollen grains obtained from the linear and ovate anthers were also germinated separately with a view to determine if there was any difference in viability and pollen tube growth. Observations were recorded 24 hours after the experiment was commenced. The comparative results obtained are given in the table below:—

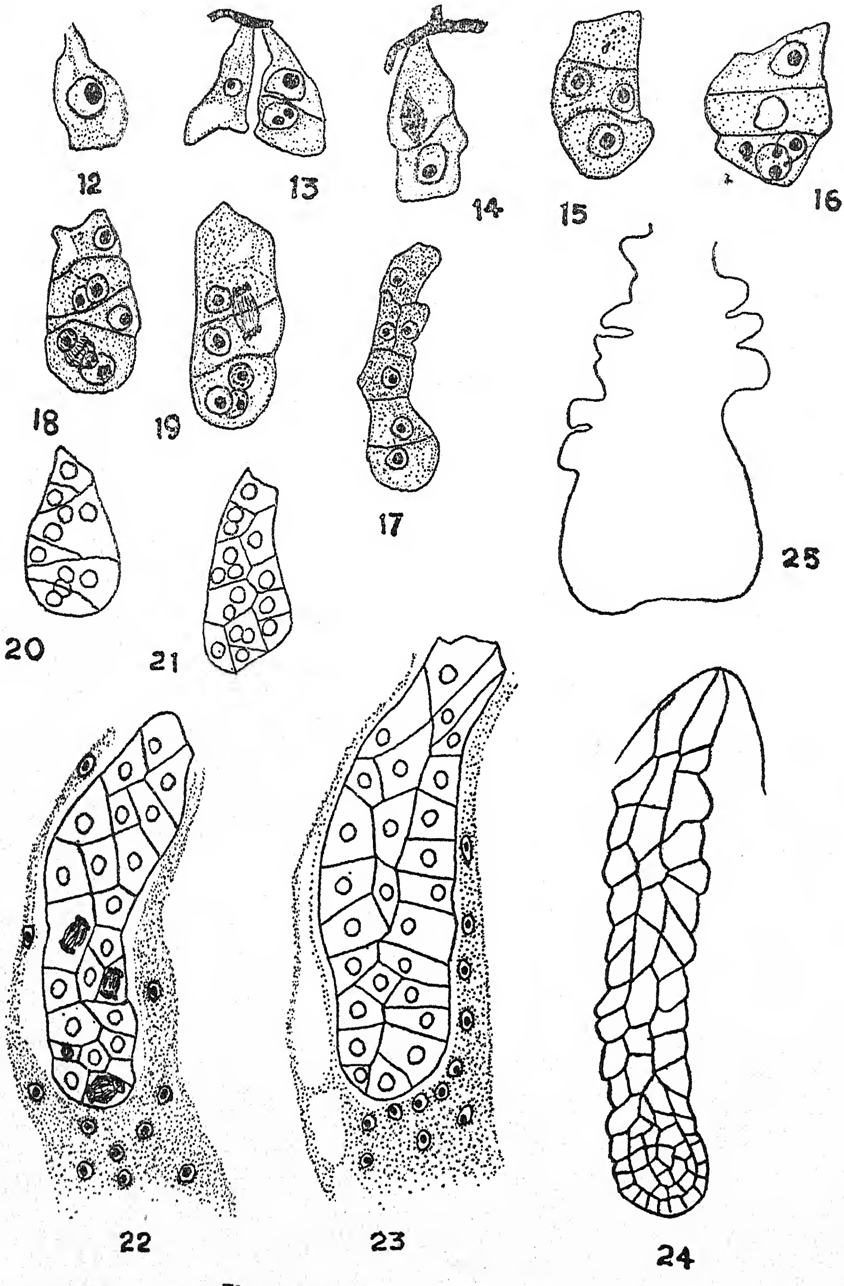
Germination of Pollen Grains

	Linear anther.	Ovate anther.
Kharif Crop .. (The monsoon period)	40 % germinated, greatest length of the pollen tube 1 mm.	20% germinated, greatest length of the pollen tube 0·8 mm.
Rabi Crop .. (The cold weather season)	20% germinated, of these the majority were with short tubes, 2% or so with germ tubes 0·7 mm. long.	3% germinated, majority of these with short tubes, 5% or so of these with germ tubes ranging between 0·2 mm. and 0·4 mm.

The results obtained explain the cause of degeneration of a large number of ovules in off-season. This is due to the fact that only a few pollen grains send out tubes which grow at the normal rate, and reach the micropyle before the style degenerates, whereas most of the pollen tubes fail to do so and as a result the ovules degenerate due to lack of fertilization.

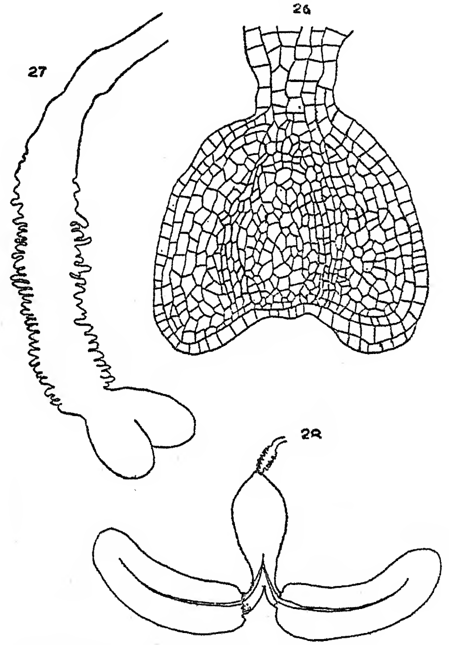
Embryogeny

The fertilized egg after a period of rest divides by a transverse wall into two cells (Fig. 13). Before any division takes place in the apical cell, the basal cell also divides transversely (Fig. 14). The middle cell of the three-celled proembryo then divides by a slightly oblique transverse wall and forms a four-celled proembryo (Fig. 15). The first division of the apical cell is generally longitudinal though transverse division is not very rare (Figs. 16 and 17). The essential parts of the embryo are chiefly organised from the products of the apical cell, whereas the major part of the suspensor is derived mainly from the products of the two middle cells. The basal cell is comparatively bigger in size and remains undivided for sometime. It divides either longitudinally, or obliquely and lies adpressed to the nucellus at the micropylar end (Figs. 20, 23 and 24). It functions as haustorium and supplies nutrition to the developing embryo from the nucellar tissue. Due to the repeated and regular



Figs. 12 to 25. *Crotalaria juncea* L.
Figs. 12—25. Stages in the development of the embryo. $\times$ 400.

divisions in the products of the apical cell as against the irregular and oblique divisions observed in the products of the two central cells of the four-celled proembryo, the embryonic zone is soon differentiated out from the suspensor. The cells of the embryonic region are smaller in size, possess conspicuous nucleus and denser cytoplasm (Figs. 20—24). The suspensor cells are usually bigger in size and have conspicuously vacuolated cytoplasm. They are irregularly arranged and form a massive cylindrical body (Figs. 23 and 24). Periclinal divisions in the embryonic zone indicate the differentiation of the tissue system at the radicular apex of the embryo. This takes place at a time when the suspensor is more or less well developed. (Fig. 24). The outer cells of the suspensor protrude out as bulbous bodies and function as haustorial cells (Fig. 27). The suspensor attains its maximum size before the cotyledons are differentiated and remains as such up to the time of germination (Fig. 28).



Figs. 26 to 28. *Crotalaria juncea* L.

Later stages in the development of the embryo. Fig. 26. Embryo-forming region differentiated from suspensor. × 75. Fig. 27. Outline drawing of the embryo with suspensor showing its typical shape. × 50. Fig. 28. Differentiation of the cotyledons: note haustorial process of the suspensor. × 75.

Endosperm

The endosperm nucleus divides long before the division of the fertilised egg. The nuclei at first form a lining layer along

the embryo-sac cavity except at the embryonal region where the cells are closely aggregated. The endosperm nuclei later multiply by free nuclear division and gradually the embryo-sac cavity becomes filled up from the sides. Wall formation commences from the periphery of the sac and extends towards the centre, and the cells become delimited by walls. The cells generally contain a single nucleus but as also noted in many other plants, more than one nucleolus are present in some cells. Sometimes as many as 15 nucleoli have been noted in a single nucleus.

Discussion

The type of embryo-sac development:—The development of the embryo-sac in *Crotalaria juncea* is of the normal type. In Leguminosæ instances of aberrant types of embryo-sac development are very rare. Herail's (4) work on *Medicago arborea* shows that the axial hypodermal cells of the nucellus divide by periclinal walls into two cells, the inner of which directly functions as an embryo-sac cell without undergoing tetrad formation. Young (11) reports another exception in *Melilotus alba* where the megaspore mother cell acts as a megaspore. Coe and Martin (1) who worked on the same plant state that the development of the embryo-sac proceeds in the ordinary way and the megaspore mother cell does divide. Jönsson (5) reports the development of the embryo-sac in *Lathyrus odoratus* to be of the 'Scilla type,' but Roy (8) who worked on *Lathyrus sativus* states that the embryo-sac development is of the normal type in that plant.

Recent investigations show that the embryo-sac development in the family Leguminosæ is of the normal type, and the aberrant types which were worked out long ago require confirmation.

Degeneration of ovules:—Absence of seed formation has been noted in many Leguminous plants of which *Albizzia Lebbek* and *Medicago sativa* are common examples. In these cases investigations have showed that degenerations result in the non-development of the female gametophyte or failure of the pollen grains to function. In *Crotalaria juncea* plants grown during the normal season do not show degeneration of the ovules to any marked extent. But when grown in off-season, non-development of seeds appears to be a common feature. Investigations show that the egg-apparatus degenerates and this is due to delay in fertilization caused by the slow rate of pollen tube growth. This can be explained as being due to the want of nutrition, as the plant completes its life cycle in a very short time during the off-season.

Embryogeny:—Comparatively very little work has been done on the embryogeny of Leguminous plants. Souèges (10) who worked out the embryology of *Medicago lupulina*, *Trifolium minus* and *Lotus corniculatus* found that the details of the

proembryo differ very much, and each can be considered to represent a separate type. In all cases he observed the fertilized egg to divide by a transverse wall into two cells, apical and basal. There was a difference in the employment of the basal cell in the formation of the suspensor in the different types. Of these *Lotus corniculatus* shows similarity in the development of the proembryo with *Crotalaria juncea.* In the plants investigated by Souèges, the suspensor was observed to be rather small, but in *Crotalaria juncea* it is a massive structure. Cook's (2) work on *Crotalaria sagittalis* is not in detail. He found a massive haustorial suspensor in this plant. Guignard (3) who worked on a large number of Leguminous plants observed considerable variation in the formation of the suspensor.

Summary

The curvature of the ovules is determined by the mechanical pressure exerted by the wall of the carpel. The ultimate condition of the ovules is anatropous.

A single archesporial cell differentiates in the third layer of the nucellus. It either directly acts as a megaspore mother cell or cuts off a parietal cell before doing so.

The megaspore mother cell undergoes the usual reduction division. It forms an oblique 'T'-shaped tetrad of megaspores, the chalazal one being functional.

The mature embryo sac is eight nucleate and is of the normal type. The fusion of the two polars and the disorganisation of the antipodals with the chalazal part of the embryo-sac takes place before fertilization.

Unicellular hairs are present in large numbers at the base of the style inside the ovarian cavity and along the ventral suture of the carpel.

Failure of pollen tube growth and the occasional degeneration of the functional megaspore appear to be the cause of sterility of a large number of ovules in off-season.

The fertilized egg divides into an apical and a basal cell by a transverse wall. The apical cell by further growth forms the embryo while the basal cell gives rise to three cells arranged in a row, of which the second one from the top appears to give rise to the suspensor.

The suspensor is massive and haustorial. It attains its full development before the differentiation of the cotyledons and remains as such till germination. The cotyledons are leafy and the radicle is fusiform.

The endosperm nucleus divides by free nuclear division before the fertilized egg begins its first division. The endosperm

nuclei form a lining layer along the embryo-sac wall. It gradually invades the central region and wall formation begins centripetally from the embryo-sac wall. The endosperm cells become delimited with walls before degeneration.

The writer has the pleasant duty to offer his sincere thanks to Mr. I. Banerji for help and encouragement during the course of the investigation.

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Explanation of Plates

The figures were drawn with the aid of a camera lucida at table level. The magnification of each figure is given separately.

Plate II.

Fig. 1. Origin of the archesporial cell in the third layer of the nucellus. ×95.

Figs. 2 & 3. Division of the "cover cells". ×95.

Fig. 4. Megaspore mother cell in synapsis. ×95.

Fig. 5. Heterotypic metaphase. ×1,500.

Fig. 6. Interkinesis: Note reconstruction nuclei with the homotypic split in the chromosomes. ×1,500.

Fig. 7. Homotypic division. ×1,500.

Fig. 8. Formation of megaspores following homotypic division. ×1,500.

Fig. 9. A tetrad of megaspores: note the disintegration of the upper three megaspores of the tetrad. ×1,500.

Plate III.

Fig. 10. Increase in size of the functional megaspore. Degeneration product of the three other megaspores forming a black mass at the top. ×750.

Fig. 11. Binucleate embryo-sac. ×750.

Fig. 12. Four nucleate embryo-sac (composite drawing from two sections). ×750.

Fig. 13. An eight nucleate embryo-sac (composite drawing from two sections). ×750.

Fig. 14. An eight nucleate embryo-sac in which the synergids and antipodals are being differentiated. ×750.

Fig. 15. Egg-apparatus.

Fig. 16. Synergids with vacuoles at the base and without any filiform apparatus. ×750.

Fig. 17. An aberrant type of embryo-sac showing degenerated egg apparatus and the fusion of the five other nuclei near the chalazal end of the sac. ×150.

Fig. 18. A stage in the fusion of the polar nuclei. ×750.

Fig. 19. Primary endosperm nucleus. ×750.

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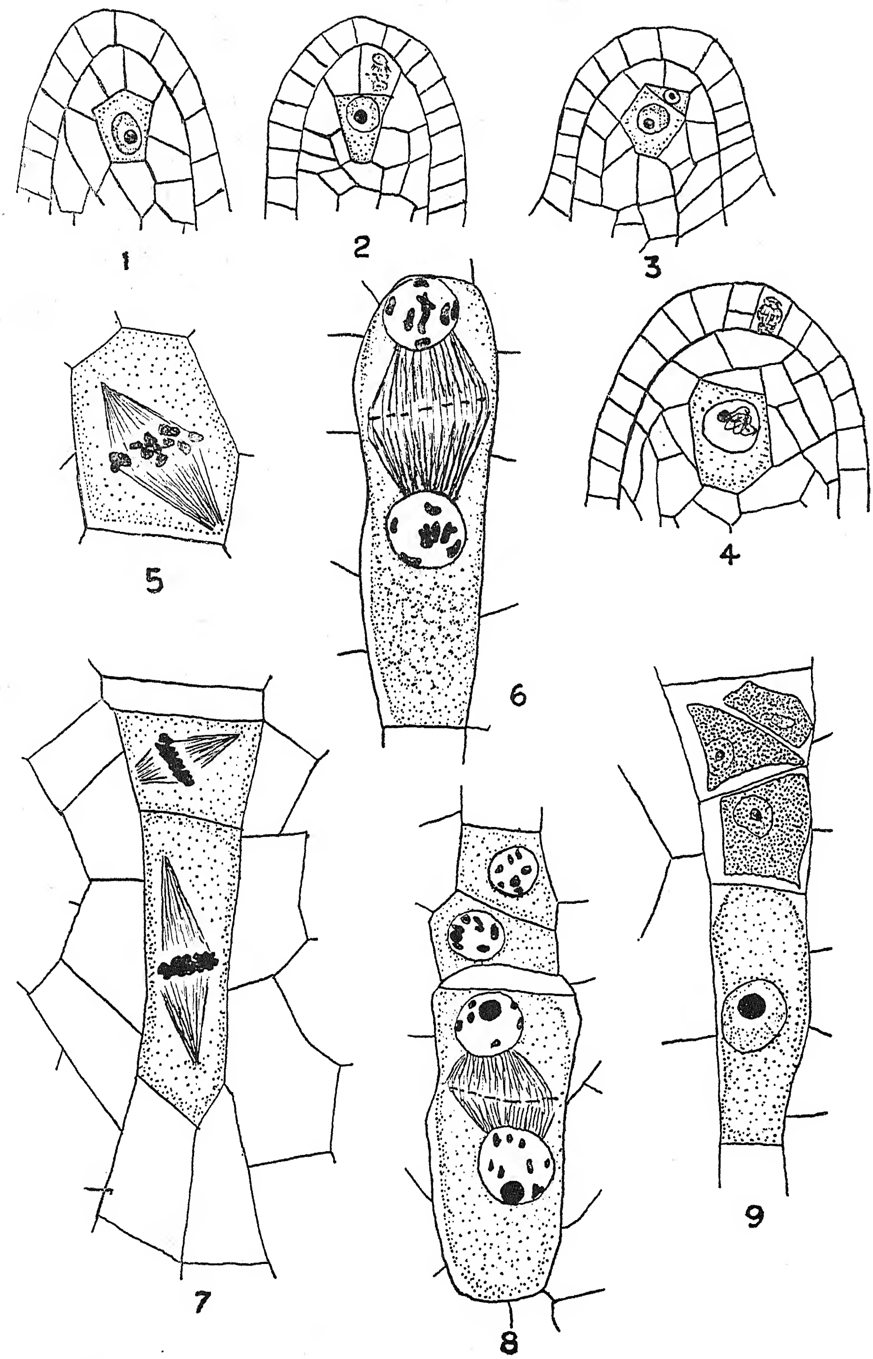

K. K. SAMAL—*CROTALARIA JUNCEA* L.

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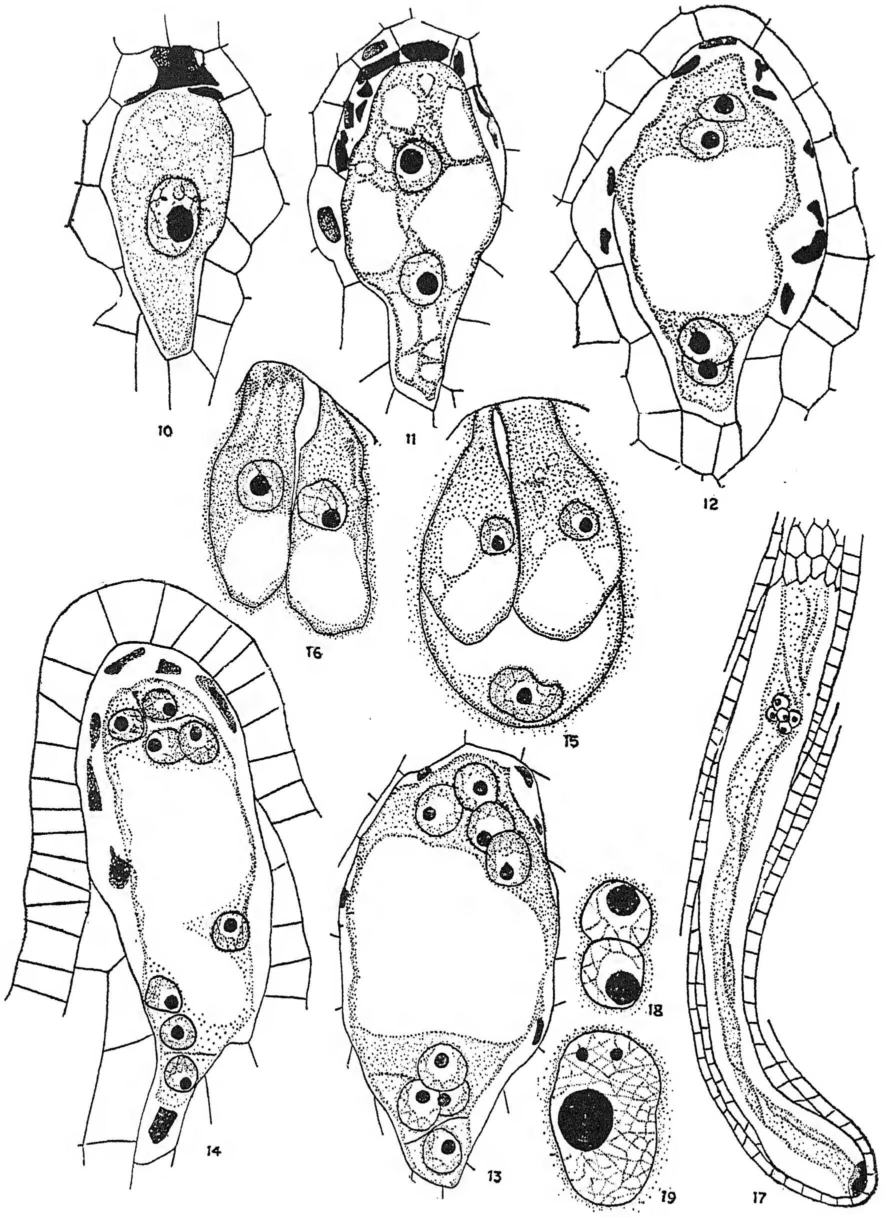

K. K. SAMAL—*CROTALARIA JUNCEA* L.

A SCHEME FOR THE DISSEMINATION OF THE KNOWLEDGE OF PLANT DISEASES IN INDIA, AND SUGGESTIONS FOR CONTROL OF DISEASES*

BY

H. CHAUDHURI

Panjab University

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India is primarily an agricultural country. Though the majority of its population live on the land, they live rather miserably. High rates, uncertain supply of water, poor quality of seeds, etc., are a few of the causes responsible for the pitiable condition in which our peasants live. In certain provinces, with low rainfall, irrigation has solved the question of water supply, but the cess remains very high. Again political conditions which help the foreign countries to dump their agricultural produce in India often are responsible for bringing about a miserable plight. A few years back Punjab produced a most bumper crop of wheat, but it could not export the grain outside the province as the wheat dumped in Calcutta and Karachi ports from a foreign country and selling at a very low rate, put the growers of the Punjab at a great disadvantage, for, after paying the water cess and the railway freight, they couldn't compete with the foreign wheat — in fact they could not even get back the money they had paid. I am not offering any solution in this paper for this — that I leave to the economists and politicians of our country. Here I want to bring to your notice the failure and low yield of our crops due to various diseases and how a knowledge about the disease could prevent this to a great extent. The losses due to cryptogamic diseases are simply enormous and they cause much more loss than that caused by all the insects together. In Germany out of a total annual loss of over 80 million pounds sterling, nearly 50 million pounds sterling were lost owing to cryptogamic diseases. Yet it is more difficult to persuade Government to make adequate provision for the study of plant diseases due to cryptogamic parasites than for the insect pests. In the last

*Read before a joint meeting of the sections of Agriculture and Botany, Indian Science Congress, Calcutta, January 1935.

Imperial Mycological Conference, Butler rightly mentioned, "A locust invasion could scarcely be missed by the least observant, but it was often difficult to persuade the growers or the agricultural authorities, to say nothing of the Government, that invisible cryptogamic parasites were eating the crops." Hence the great importance of disseminating knowledge of plant diseases. I shall first quote a few figures regarding loss due to diseases. Germany lost annually over 18 million pounds from cryptogamic diseases of potato alone; similarly Irish Free State from one disease of potato, *viz.*, virus disease, lost over 4 million pounds annually. Cereal rusts alone were costing the world over 100 million pounds sterling annually and the foot-rot diseases were causing still more loss. Similarly in the case of tropical and sub-tropical crops, perhaps greater loss was caused by the mass attack of weak and obscure parasites. During the last 5 years, I have been investigating the wither-tip disease of the *Citrus* in the Punjab. It is caused by *Colletotrichum gleosporioides* which is a weak parasite. It has been observed that certain conditions of the environment being favourable it causes as much loss as any of the so-called major diseases and by which whole plantations may be wiped out. It has also been noticed that newer plantations suffer more, for the growers being attracted by the very profitable *Citrus* orcharding in the Punjab, have been quickly developing new orchards with any kind of nursery-men stocks that they could lay their hands on. As neither the nurserymen nor the buying public have any knowledge of diseased stocks, they sell and buy these diseased plants and after 4 or 5 years of looking after, they find their orchards useless and suffer great loss. If the buying public had the least knowledge about diseases in plants, they would never have purchased diseased nursery plants; for, when they do not buy a diseased cow or a diseased horse, why should they buy diseased plants if they knew anything about it? Then how should we proceed? There are three recognised means of dealing with diseases.

First, by growing disease-free plants—proper selection of plants and also of seeds. Preferably choosing resistant varieties wherever possible.

Second, to control the disease when possible by spraying with fungicides and insecticides either before the disease appears or after it has appeared.

The *third* method is by means of legislation—by putting up a quarantine against exporting countries where diseases of the imported plants are known to exist.

The first two methods of disease control are to be resorted to by the cultivators and are to be applied under proper guidance. Propaganda work by means of literature published in vernacular and lectures with lantern slides have to be carried on to convince the cultivators, and arrangements for distribution of seeds and

nursery stocks at reasonable price have to be made. This work could be taken up easily by the District Co-operative Societies and by district agricultural officers. Arrangements for keeping dusting and spraying machineries and stocking of dusting powders and other chemicals have to be made through these agencies. These machineries could be loaned out under supervision of a mechanic at a nominal cost and the chemicals sold at cost price. For the first three years the cultivators and orchardists could be elected members of such district societies without any subscription, but later when they would be convinced about the very great advantage of being a member of such societies, a subscription fee might then be charged. At present, the district authorities no doubt distribute seeds, etc., in many places, but that is not enough. They must protect the crop as well when it is growing. The prosperity of the farmer means prosperity of the country. *Another alternative,* specially when there are a number of cultivators and orchardists, is to form a *Co-operative plant-protection society* amongst themselves. In certain parts of South Africa the Co-operative Plant-protection Societies formed by the growers are doing marvellously well. A few years back when the natives in Tanganyika wanted to have their own coffee plantations, the white people there who had their own plantations objected to this for they said that the natives would naturally keep their plantations in such a bad condition that diseases from the native plantations would affect the plantations of the white people. Though the government there permitted the natives to have their plantations, yet owing to this agitation they passed a law authorising the plant inspectors to burn down any native plantation that was found to be in a bad state and affected by diseases. This, however, did not frighten them and they started their plantations after forming a Co-operative Plant-protection Society and it was admitted by a representative from Africa, during the last session of the Imperial Mycological Conference in London last September, that the native plantations were in a much better and cleaner condition than many of the orchards belonging to the white people. This I have mentioned only to illustrate what really could be achieved by such a plant-protection society even against such great odds.

At the headquarters of every district, there should be a model agricultural farm where not only selected seeds and plants will be grown but every contrivance should be available for protection against diseases. An assistant with knowledge of diseases should be appointed, who will not only look after the farm, but also tour all over the district and report the incidence and presence of particular diseases and diseases in general. He should advise the growers on the control method and help them in controlling epidemic diseases. These plant pathological assistants or plant inspectors should be in regular touch with the Government Pathologist belonging to the province. Whenever necessary this band of plant inspectors may be called by the Government Plant Pathologist to keep them acquainted with not only modern methods of control but

also train them to look up obscure diseases which also cause heavy losses to the country. Another important work to be taken up by these plant inspectors will be certification of nurseries. People will be advised not to buy plants from uncertified nurseries and these certificates will have to be renewed six-monthly. Many of the diseases spread through the nursery plants and unless these are kept in a disease-free condition, there will be very little chance of having disease-free gardens. It should not be very difficult by control methods to keep the nurseries free.

I will now say a few words about the third method of disease control, *viz.*, protection by means of legislation. At the last meeting of the Imperial Mycological Conference a resolution urging the adoption throughout the British Empire of a uniform health certificate for plant imports and exports as a protective measure against the distribution of plant diseases was passed. It was also recommended that steps should be taken by all Empire countries to prohibit air-passengers importing living plants or plant products. In India virtually no such regulations exist. No doubt seeds and other plant materials are as a matter of routine fumigated in the Bombay and other ports, but these fumigations are really of no use in controlling cryptogamic diseases of plants. In the Bombay port these plant materials are fumigated with HCN gas. To test the efficacy of this fumigation against two common diseases of the *Citrus* plants, *viz.*, anthracnose and canker, I had a small parcel of *Citrus* twigs made up and had it fumigated at the Bombay Port, through the courtesy of Professor Dunncliff, Chemical Adviser to His Majesty's Customs Department. As soon as I received back the packet, I made similar spore-suspension from spores in the acervuli from treated as well as from untreated diseased twigs and plated them after dilutions. When incubated at 22·5°C. for two days and the number of colonies were counted and compared, no difference whatsoever was found between the treated and the untreated samples. Exactly similar results were obtained with regard to canker. Hence the present method of routine treatment with HCN is of no use for these diseases, though they no doubt will be useful for insect pests. A properly qualified pathologist should be appointed at the port who should

(1) keep the materials first in special quarantine room.

(2) issue certificates of freedom from notified diseases,

(3) spray, fumigate or dust the materials as may be necessary,

(4) isolate organisms before treatment to find out diseases liable to be imported and plating out again after treatment to see the efficacy of the treatment.

In ports like Bombay, Calcutta and Rangoon, this work could easily be taken up by the Universities there and done very efficiently and

cheaply. We have to bring home to our legislators, the danger of introduction of diseases from foreign countries. It is a well-known fact that a minor disease of a place may become a major one in a newly introduced area. I have mentioned before the very useful work that could be done by the plant inspectors. Our legislators will have to give them authority to destroy diseased plants in an orchard which remain as perpetual sources of infection and also power to prevent the growing of certain susceptible varieties that are easily attacked by diseases and from which the epidemic might spread.

Before concluding my paper, I want to indicate another direction in which we should direct our attention. In our primary, middle and secondary schools, we should see that the vernacular books on biological sciences should also contain something about plant diseases. For example, something about rusts and smuts and mildews, locusts and nematodes, etc., may be easily taught and the boys may be taken to the fields to show there the loss caused by these pests and also how moulds and bacteria, etc., destroy our valuable food materials. When they grow up, they will much better appreciate the problem than the present generation of public men and realise what a huge amount of loss is suffered by the country annually, largely owing to ignorance.

ON THE ANATOMY OF *IPOMOEA AQUATICA* FORSK., WITH SPECIAL REFERENCE TO THE DEVELOPMENT OF AERENCHYMA AS A RESULT OF INJURY

BY

D. P. MULLAN

St. Xavier's College, Bombay

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Ipomoea aquatica Forsk. (*I. reptans* Poir.) is a common herb found growing in rain pools, ditches and moist places throughout India and Ceylon. Hooker (11) calls it an annual, while Cooke (5), Duthie (7), Gamble (8) and Trimen (18) describe it as an annual or biennial. The habit of rooting at the nodes keeps the plant thriving as long as the substratum is full of water. Even when the soil dries up, as it happens during the dry season in the cases of shallow ponds, the plant is seen to pass through a resting period. As a rule, the plant thrives during the monsoon at the end of which it produces flowers and fruits. If the pond begins to dry up, the plant undergoes a change. The branches, developed under progressively dry conditions, have very short internodes and the leaves tend to be shorter and narrower. Ultimately, the branches are reduced to swollen nodule-like structures, bearing small leaves. The roots and the very much shortened branches are fully loaded with starch and are efficiently protected by a thick layer of cork. In this condition the plant seems to hibernate throughout the dry season. If such hibernating parts are planted in wet soil, they readily develop long internodes and broad leaves, typical of the plant during its monsoon phase. Cooke (5) and others describe it as an aquatic plant, but a study of the vascular system of the stem, the position and structure of the leaves, as well as the ready adaptability to comparatively dry habitats, appear to indicate an ancestral terrestrial life. The plant may be regarded as semi-aquatic or amphibious, for though it thrives best in a marshy soil, it can adapt itself to living on well-drained soil. Furthermore, if the plant is trained as a twiner, the branches readily twine in the sinistrorse fashion, characteristic of other Ipomoeas.

The distal ends of the branches are held above the surface of the water. If the level of the water is raised, in the case of plants rooted in the wet soil, the branches come up through the water

almost vertically and reaching the surface, assume the floating position. This habit is of evident use to the plant as it keeps its leaves and flowers in the air. Stomata and glandular hairs occur on the young stem which is covered with a striated cuticle. Each glandular hair (Fig. 1) consists of a short stalk-cell, seated in a depression, and a peltate, discoidal head, divided by vertical walls into 10-13 cells, holding brownish contents. Cork arises at an early stage and is superficial in origin, the phellogen layer arising, as in *I. Pes-caprae* (12), in the epidermis (Fig. 2). The cork layer remains transparent, the sub-epidermal anthocyanin, which develops in parts exposed to light, showing through it. The whole outer surface of the stem becomes infested with Algae, etc. The superficial covering of cork, apart from affording protection against the attacks of aquatic organisms, may also be adding to the buoyancy of the plant. Lenticels occur on the exposed parts of the stem and petiole. As in *I. Pes-caprae* (12), the cortex consists of three zones, *viz.*, the sub-epidermal three-layered chlorenchyma, 3-4 layers of feebly-developed collenchyma and 2-3 layers of parenchyma respectively (Fig. 3). Czapek (6) has investigated the "latex" cells of the Convolvulaceæ. In *I. aquatica*, vertical rows of thin-walled (somewhat suberised) cells, holding a milk-white sap, occur between the collenchymatous and parenchymatous zones of the cortex (Figs. 4, 5). The secretory cells are shorter and broader at the nodes, but in the region of the internodes they attain a considerable length. In plants grown under dry conditions the contents of the secretory cells get meagre. In young parts of the stem the cortex is continuous, while in mature parts it becomes lacunar (Figs. 20, 22). The lacunæ are lysigenous in origin and occur in the inner parenchymatous zone. The regions around the secretory cells are left intact and appear like bridges of parenchyma, separating the cortical lacunae from one another. In parts of the stems kept submerged, the lacunæ are more enlarged than in parts floating on water or trailing on marshy soil. The endodermis holds large starch grains, which in young parts are enclosed in pale green chloroplasts. These grains move readily with the change of position of the stem and seem to serve as a statolith apparatus. The stele is broad, as in land plants. Islands of intraxylary phloem are present in the stem. As in *I. Pes-caprae* (12), secondary growth is somewhat irregular owing to the unequal distribution of the xylem mass. The secondary xylem vessels are more strongly developed in three tracts — two being placed laterally, one on each side of the stem, and the third one occupying the basal region, *i.e.*, the pole opposite the insertion of the leaf. According to Solereder (17), the restriction of secondary xylem to distinct tracts is a characteristic of many convolvulaceous lianes. Some of the secondary xylem vessels have very wide lumina. Lignification of xylem, pericyclic bast fibres and collenchyma is feeble in the stems floating

Fig. 5: L. S. stem, showing secretory cells (*s*) in the pith: *st.* starch. (× 240); Fig. 6: T. S. stem, showing pith cells. (× 240); Fig. 7: T. S. stem, showing diaphragm tissue. (× 240); Fig. 8: T. S. petiole: *ch*, chlorenchyma; *c*, collenchyma. (× 500); Fig. 9: Glands on leaf: *A*, on upper surface; *B*, on lower surface. (× 500); Fig. 10: T. S. root: *p*, phellogen; *c*. lacunar cortex with chloroplasts. (× 240).

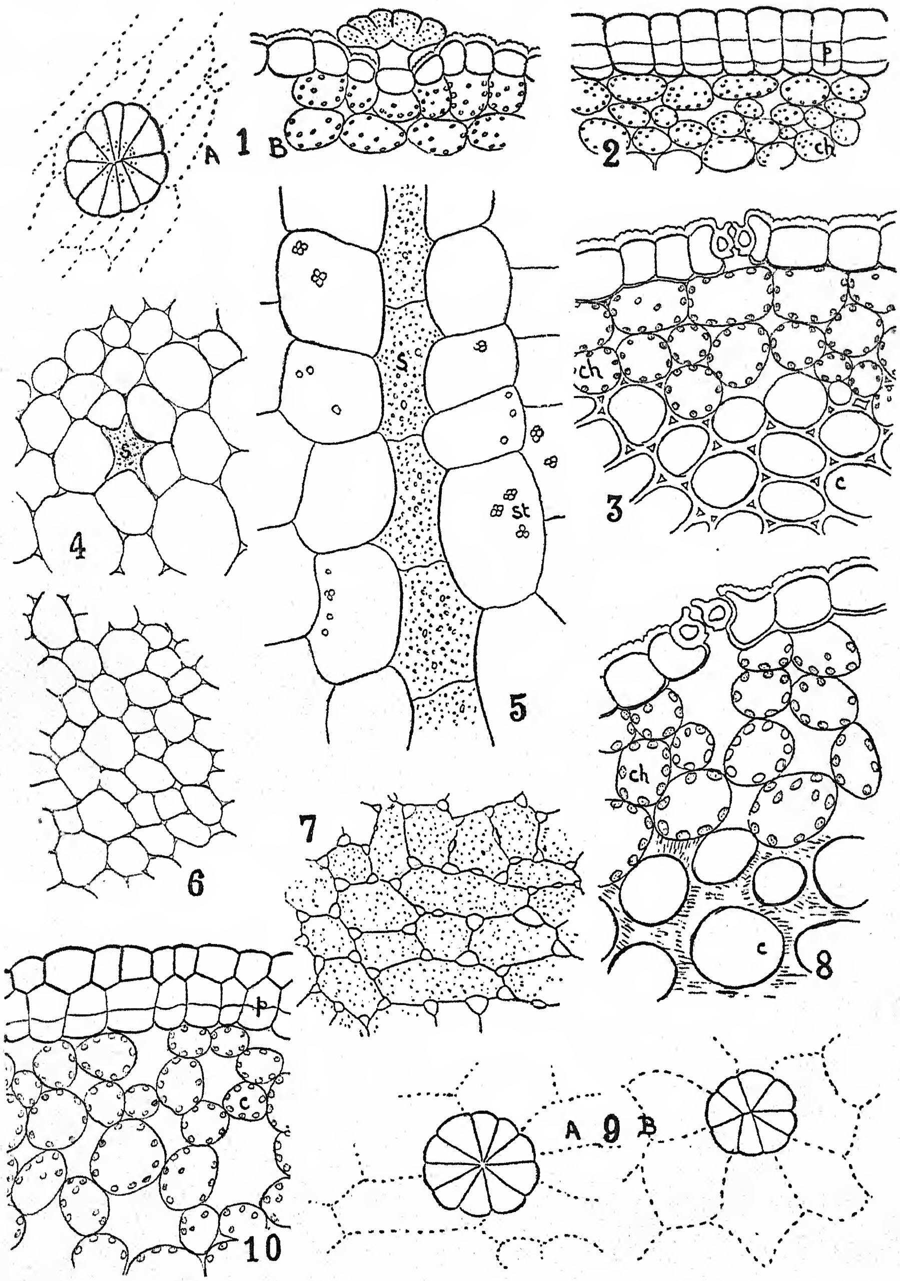

Fig. 1: A gland on the stem: *A*, in surface view; *B*, in T. S. (× 500); Fig. 2: T. S. stem, showing phellogen (*p*) in the epidermis: *ch*, chlorenchyma. (× 240); Fig. 3: T. S. stem: *ch*, chlorenchyma; *c*, collenchyma. (× 500); Fig. 4: T. S. stem, showing a secretory cell (*s*) in the cortex. (× 240);

on water, but is more pronounced in those living on dry soil and especially in cases of branches trained as twiners.

Near the growing point, the pith is composed of thin-walled polygonal cells, with small intercellular spaces (Fig. 6). At an early stage, however, the pith begins to get resorbed by the formation of a lysigenous air-passage which originates by the breaking down of the central medullary cells. The lysigenous air-cavity, thus initiated, slowly expands outwards in a centrifugal manner, by the breaking down of the central parenchyma all round, leaving only the peripheral medullary cells. Thus in the mature stem, the pith is mainly replaced by a large axile lacuna and is represented by only 3-4 rows of roundish polygonal cells, extending from the inner face of the groups of intraxylary phloem (Figs. 14, 20). The cortical as well as the medullary lacunae not only facilitate aeration but also add to the buoyancy of the stem. Secretory cells, similar to those of the cortex, occur in the peripheral pith cells (Figs. 14, 17). Vertical rows of crystal-idioblasts, each containing an aggregate crystal of oxalate of lime, are mainly absent in plants floating on water, but they appear in the cortex, pith and conjunctive tissue of plants living in comparatively dry situations and in the twining branches. The central air-passage of the mature stem is divided into sections by the diaphragms which occur at the nodes. The nodal diaphragms of *I. aquatica* resemble, in structure and function, those of other water and marsh plants described by Blanc (3), Arber (1) and others. The diaphragm tissue consists of a few layers of short-armed, irregularly stellate cells with small interstitial spaces between (Fig. 7). That the diaphragms form a safeguard against flooding of the entire central air-passage is easily demonstrated by cutting open an internode and keeping it submerged. Under the circumstances, though the cut internode gets flooded with water, the latter does not pass beyond the diaphragms into the intact internodes on either side, even after several days immersion. In plants floating on water, crystal idioblasts, each holding an aggregate crystal of oxalate of lime, occur mainly among the peripheral cells of the diaphragms; while in plants growing under dry conditions, the diaphragms act as storage tissue, being fully loaded with starch and sphaeraphides. Both the cortical and the medullary lacunæ persist, though in a less pronounced form, even when the plant is grown out of an aquatic *milieu*. In the case of the twiner, the pith is not resorbed to such an extent as in plants floating on water, 6-8 layers of the pith, from the inner face of the intraxylary phloem groups remaining intact. Constantin (4) has shown, in the case of other amphibious plants, that it is the aquatic medium which determines the increase in the cortical and medullary lacunae. In the mature stems of *I. aquatica*, under dry conditions or as a twiner, the axile air-passage remains very narrow, the diameter varying from less than 1 mm. to about 4 mm.; while in stems floating on water, it reaches a diameter upto 1 cm. Again, if some

Fig. 16: T. S. stem, showing the arising of aerenchyma. (× 150); Fig. 17: T. S. stem: Explanation in the text. (× 150); Fig. 18: T. S. petiole, showing the arising of the meristem in the pith. (× 150); Fig. 19: T. S. stem; Explanation in the text. (× 150).

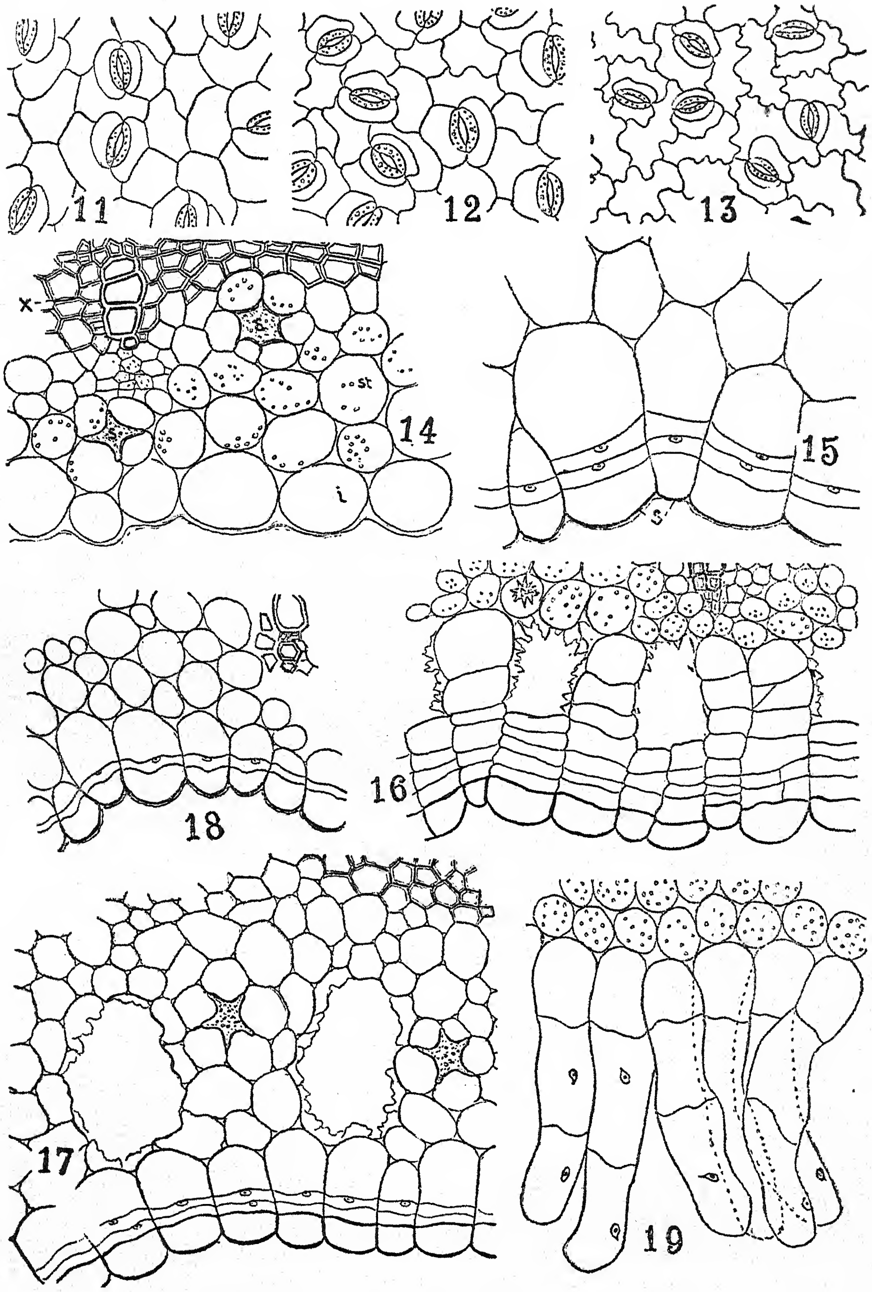

Fig. 11: Leaf: upper epidermis. (× 240); Fig. 12: Leaf: lower epidermis. (× 240); Fig. 13: Leaf (dry soil): lower epidermis. (× 240); Fig. 14: T. S. stem, showing part of the stele: *x*, xylem; *s*, secretory cell; *st*, starch; *i*, innermost layer of pitch. (× 150). Fig. 15: T. S. stem, showing the arising of the meristem in the pith: *s*, suberised walls. (× 240);

of the slender stems of the plant trained as a twiner are placed in a neighbouring tub of water, they, after a time, show a far greater diameter than that of the twining branches of the same plant, the increase in diameter being mainly due to an enlargement of the cortical and especially of the medullary lacunae.

The leaves of *I. aquatica* rise wholly into the air, being held well above the surface of the water by the long petioles. The leaves are adapted to a life in the air and soon die if held under water. The petiole repeats the general structure of the stem and bears glandular hairs and stomata. To sustain the erect position of the petiole, the outer collenchymatous zone is far more developed than in the prostrate stem and consists of 6-7 layers. A comparison of Figs. 8 and 3 (both magnified equally) brings out the contrast between the collenchymatous zones of the aerial petiole and of the floating stem. The sub-epidermal chlorenchyma is also more fully developed. Secretory cells and crystal-idioblasts occur in the cortex and in the peripheral pith cells. Vascular bundles are arranged in an almost complete ring open towards the adaxial surface. Chloroplasts occur in the xylem parenchyma. Cork arises superficially and makes its appearance first towards the basal part of the petiole. In the lamina, the upper and lower epidermis are not much differentiated in the case of floating plants (Figs. 11, 12), while in plants living under somewhat dry conditions, the lower epidermis, in surface view, shows cells with irregularly wavy walls (Fig. 13), a characteristic feature of many mesophytes. Stomata, with subsidiary cells placed parallel to the pore, occur on both surfaces, being about 180 per sq. mm. on the upper and 275 on the lower. Glandular hairs, similar to those of the stem, occur on the lamina, being more numerous and more fully developed on the upper than on the lower surface (Fig. 9). The leaf structure is typically bifacial, consisting of 3-4 layers of palisade cells and 6-7 layers of spongy tissue. Crystal-cells, containing sphaeraphides, occur under the innermost palisade layer. The veins are surrounded by a sheath of colourless parenchyma. In the midrib, isolated groups of phloem, with crystal-cells, occur on both sides of the arc of xylem. Secretory cells accompany the main as well as the minor veins.

In the case of plants floating on water, adventitious roots develop freely at the nodes, below the leaf bases. If the water is pretty deep the roots remain free-floating for a considerable time. Such roots are feathery, very slender and devoid of root hairs. They are conspicuously green and evidently exercise an assimilative function. If these roots are placed in wet soil they develop conspicuous root hairs within a week and function as soil roots. The stele is contracted and consists of 5-10 radially placed vascular bundles. Secondary xylem arises in irregular patches separated by broad medullary rays. Secretory cells, similar to those of the shoot region, occur in the root being associated with the inner face of each phloem bundle. The narrow pith is composed of thin-walled

polygonal cells with intercellular spaces. As in the marshy plants, the aerating system of the root is supplied by the primary lacunar cortex. The latter is composed of roundish polygonal cells with prominent schizogenously-formed air-spaces (Fig. 10). The outer cortical cells hold chloroplasts, with included starch, in parts exposed to light. The mature soil roots are stout and soft and develop in the cortex large, lysigenously-formed air-spaces in addition to the schizogenous lacunæ previously described. The lysigenous air-spaces are equal in number to the phloem groups and are placed on the same radii as the latter. These radially-placed lacunæ are separated from one another by 2-3 seriate bridges of cortical parenchyma. In the root, the cork is superficial in origin (Fig. 10). By the advent of the dry season, the old roots and the nodule-like branches get heavily loaded with starch and are covered with many-layered cork. As previously noted, in this condition they hibernate throughout the dry season. In such old roots, the otherwise soft cortex is seen to be strengthened by the development of strongly-lignified stone cells which occur among the loose cortical parenchyma. Similar stone cells, isolated or in small groups, are also to be met with in the cortex of the nodule-like hibernating branches. It is interesting to note that such stone cells do not occur in the functional, floating branches, but are a feature of the partly-buried hibernating parts of the stems.

In the stem, under normal conditions, the innermost layer of the pith, which delimits the central air-passage, is composed of clear, roundish polygonal cells (Figs. 14, 20). During the anatomical investigations, it was found, however, that at times the cells of this innermost layer get radially stretched and become meristematic, giving rise to what appears like a phellogen layer (Fig. 15). As this is not a constant feature of all internodes, a search was made for the probable cause of this phenomenon, when it was seen that the internodes showing this feature bore some mark of injury. Furthermore, it was found that in the neighbourhood of the wound, the large secondary xylem vessels were plugged by the development of thyloses. In order to see whether the arising of a phellogen in the pith was due to injury, plants kept under different conditions were experimented upon. Thus if an internode is cut across and left floating on water it is found that, though at the time of the cut the pith cells were normal, within a couple of days they begin to develop a distinct phellogen layer. Again, in order to see whether it was the injured internode alone which develops the meristem, several healthy stems were selected and the alternate internodes were wounded on one side in various ways, such as, by transverse and longitudinal cuts, by punctures or by peeling off of small areas of the outer cortex, etc. By such experiments it is found that, in every case, it is the injured internode that developes the meristem in the pith, while the neighbouring intact internodes show the normal roundish polygonal cells. Even when a stem is cut across near a nodal diaphragm and the latter is punctured, before replacing the

stem in water, the internode next to the punctured diaphragm shows, after a time, the same type of meristematic activity in the pith as is seen in the cases of the injured internodes described above. Thus the chief cause of this remarkable behaviour of the pith cells seems to be a disturbance of the close atmosphere of the medullary air-passage. An examination of such injured internodes, in nature as well as in experimental plants under different habitats, provide the following data as to the structure and development of this secondary tissue in the pith.

If the injury is slight and only a few of the superficial cells of the cortex are involved, it gets healed up by the formation of wound cork. But if the injury is such as to allow the entrance of water into the central air-passage, the innermost layer of the pith gets stimulated and gives rise to a meristem. The cells in question first elongate in a radial direction and a phellogen layer is soon cut off (Fig. 15). The innermost walls of the cells giving rise to the meristem, *i.e.,* the walls surrounding the central lacuna, get suberised at an early stage and later, the whole ring of inner cells get suberised. If the injury occurs in young internodes, before the pith is fully resorbed, the phellogen, as a rule, arises in the same ring of cells which, in normal internodes forms the innermost layer of the pith. Under such circumstances, the suberised walls remain in contact, for a time, with the pith cells that have not yet disorganised. The pith meristem arises first at the point which is immediately under the seat of injury and then spreads up and down the long medullary lacuna, till it reaches the nodal diaphragms at either end of the injured internode. The innermost layer of each diaphragm, *i.e.,* the layers facing the injured internode, then establish a similar phellogen layer and the external cell walls get suberised. It is interesting to note that only the cells which face the injured internode become meristematic, while the rest of the cells of the same diaphragm, including those facing the next uninjured internode, remain unchanged. Thus in a couple of days of the injury, the entire inner surface of the hollow internode gets suberised. The secondary meristem thus established all round the medullary lacuna, then begins to cut off more cells in a centrifugal manner, with the result that the ring of suberised cells are slowly pushed towards the centre of the hollow internode. In the case of plants living in an aquatic *milieu,* only the innermost layer remains suberised, while the rest of the cells have walls of cellulose. As the zone of newly-formed cells increases in thickness, some of the cells, nearest the xylem ring, break down and give rise to radially placed, lysigenous air-cavities (Figs. 16, 21). In the case of submerged branches, the cells of the pith and even of the conjunctive tissue may get disorganised at an early stage and form lysigenous cavities, separated by pluriseriate bridges, supporting the secretory cells, as in the cortex (Fig. 17). As more cells are cut off by the meristem, the innermost suberised cells ultimately meet in the centre of the stem (Fig. 22). Thus in injured internodes, the originally existing central air-passage gets filled with a spongy

tissue. The latter is composed of loosely-arranged more or less isodiametric or slightly radially-stretched living cells, showing at times conspicuous nuclei. The cell walls of this tissue are not suberised but give the reactions of unaltered cellulose. A similarly developed secondary tissue also fills up the medullary lacuna of the petioles and flower stalks when they happen to sustain an injury (Fig. 18). In all cases, at the seat of injury, the cells of the cortex and of the conjunctive tissue become meristematic and give rise to wound cork. If the cut happens to be a long one the wound gapes open, being efficiently protected by a continuous sheath of suberised tissue, which runs from the inner pith to the outer epidermal cork along the wound (Fig. 23).

This secondary, air-containing tissue, which arises as a consequence of injury, is comparable to the aerenchyma which is of common occurrence in plants growing in wet soils. Schenck (14), who was the first to describe the tissue, restricts the term aerenchyma to the ventilating tissues of secondary origin which are homologous with cork, while Goebel (9) and Haberlandt (10) prefer to define the scope of the term from the ecological or anatomico-physiological standpoint. The mature spongy tissue of *I. aquatica,* though resembling in some respects the aerenchyma of the stems and roots of plants investigated by Schenck (14), Rosanoff (13), Witte (19), Schrenk (15) and others, differs from these in two important points, *viz.,* that it arises as a consequence of injury and that it is intrastelar in origin. Since, under normal conditions, the injury leads to a flooding of the central air-passage, the early formation of a suberised sheath all round the lacuna affords protection, primarily against decay by the action of water and secondarily, against the attacks of aquatic micro-organisms, etc. Like the outer surface of the stem, the inner surface of the medullary lacuna also gets infested with Algae, etc., in the case of internodes which get flooded. It is worthy of note that if internodes were cut across, injected with water and submerged, those bearing a suberised layer in the pith (as a result of previous injury) are able to live, while normal internodes (bearing no suberised layer) decay within a few days. Furthermore, the suberised walls may also add somewhat to the buoyancy of the injured part. The secondary, non-suberised, air-containing tissue which fills up the lacuna may be regarded as a form of aerenchyma which also acts as a floating tissue, enabling the injured part to keep at the surface of the water. The development of the spongy tissue seems to depend upon the size of the wound and the consequent volume of water collected in the medullary lacuna. Thus it is seen that in the case of an injured internode, having a wide central passage, which gets flooded, the development of the spongy tissue is either very slow or is even inhibited. On the other hand, in slender stems, or in petioles, where very little water has as yet entered through the injured part, the aerenchyma develops more vigorously. In the latter case, the radial

elongation of the cells is far more pronounced (Fig. 19) and the tissue closely resembles the aerenchyma of other plants described by Scott and Wager (16), Batten (2), and others. In *I. aquatica*, the development of an aerenchyma, as a result of injury, seems to be an acquired habit, for it persists in cases of plants grown out of an aquatic *milieu*. Thus on wounding the internodes of plants living on drained soil or of the twiner, the pith cells become meristematic and proceed to cut off cells in the manner described previously. It is worthy of note, however, that in plants living in a dry situation, the aerenchyma develops feebly and is confined only to the seat of injury, the greater part of the innermost pith cells remaining unchanged. Furthermore, in such cases, more of suberised tissue is developed and less of air-containing tissue. Thus 3-4 rows of the innermost cells show prominently suberised walls, while the non-suberised tissue is composed of cells which are more compactly arranged, there being no lysigenous cavities. Again, starch grains and crystal-cells, each containing a sphaeraphide of calcium oxalate, appear in the non-suberised tissue of the stems living in dry situations, while in those floating on water they are mostly absent.

Summary

I. aquatica is a semi-aquatic plant which passes through a hibernating phase if the soil gets dried up.

Glandular hairs are present on the stem and leaves.

Rows of secretory cells, holding a milk-white sap, occur in the stem, leaf and root.

The cortex of the stem and root shows air-cavities like those of marsh plants.

In the stem, the pith gets replaced by a central air-passage which is divided into sections by the nodal diaphragms.

If an internode gets injured, the cells surrounding the medullary lacuna give rise to a phellogen layer.

Towards the centre, the phellogen produces a suberised layer of cells which acts as a protective sheath against the action of water which may enter through the wound.

Towards the vascular ring, the phellogen produces a non-suberised, spongy tissue of living cells, with prominent air-spaces.

The secondary spongy tissue is comparable to the aerenchyma of other marsh plants, but differs from the latter in being intrastelar in origin and in arising only in the case of injury.

Apart from aeration, the spongy mass also seems to serve as a floating tissue.

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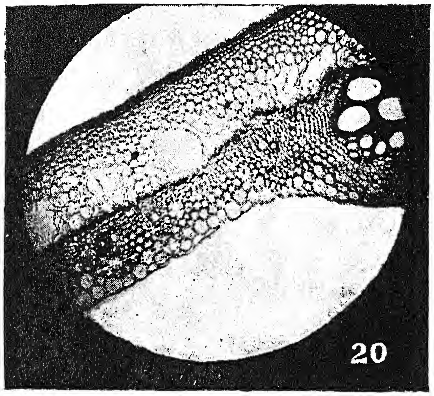
Explanation of Plate IV

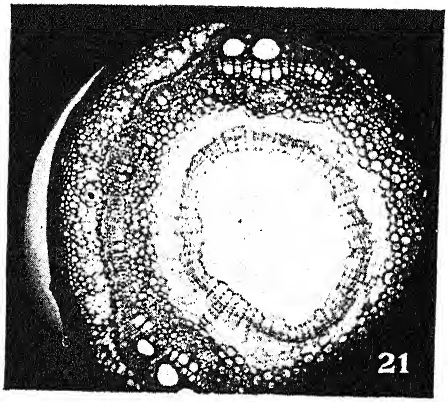
Fig. 20. Photomicrograph: T. S. part of normal internode. (× 82).

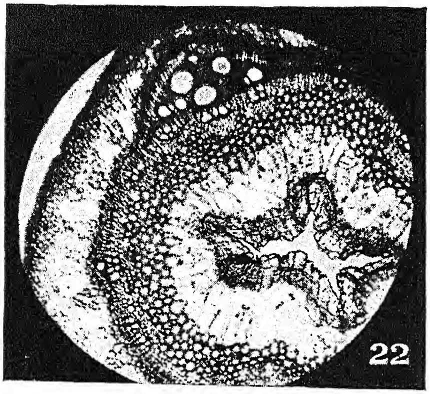
Fig. 21. Photomicrograph: T. S. injured internode. (× 60).

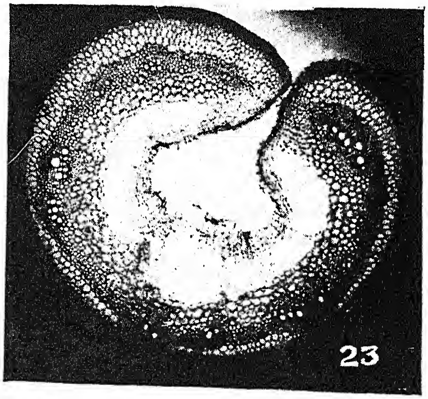
Fig. 22. Photomicrograph, showing the aerenchyma. (× 60).

Fig. 23. Photomicrograph: T. S. through the wound. (× 60).









D. P. MULLAN—*IPOMOEA AQUATICA* FORSK.

CHAROPHYTE NOTES FROM BAREILLY

BY

G. O. ALLEN

Received for publication on 24th October, 1934

The Bareilly District lies in the centre of the tract known as Rohilkhand, its position being c. 28° N. and 79° E. The average rainfall is about 42 inches, being higher towards the North as one approaches the foothills and less in the South. The climate in general is of a sub-Himalayan character. On clear days the snow-clad mountains are just visible. The drainage system is fairly complete and there are consequently few jhils. Pilibhit is the adjoining District on the East side.

My arriving at Bareilly at the end of February (1932) meant that the Charophyte season was nearly over but rice fields covered with decaying remains held out promise for the future and in what was left of pools in various waterlifts and Railway borrowpits I soon came on a number of species including several I had failed to find in the arid Agra region. The number of species forthcoming between March and May proved deceptive however, as unfortunately in my last Charophyte season in India the rains were both late and poor and water conditions were never again as favourable as when I arrived.

My first find in early March was the widespread *Chara fragilis* and within a few days I came across my old favourites, *Nitella mirabilis* and *Nitella dispersa* as also *Tolypella prolifera, Chara Braunii, C. vulgaris* and *C. contraria*. *Nitella dispersa* and *Tolypella prolifera* were both still in evidence on 22nd March, a later date than at Saharanpur. The *Nitella dispersa* was exactly the same form—with the allantoid ultimate cells — as I had had at Saharanpur. A special feature about the *C. contraria*—which applied all the gatherings I made of this species in this area—apart from the very long internodes was the production of long deciduous spines, the from thus closely approaching *var. hispidula*. The occasional occurrence of geminate spines was a distinctly unusual feature. Mr. Groves observed that the stem-cortex in places was decidedly triplostichous and drew attention to the great variation in the size of the stipulodes, a striking contrast to the neat equal ones of *C. vulgaris* to which it is closely related.

C. Braunii, C. contraria and *C. fragilis* were still in evidence as late as May 1st by which time the season had practically ended.

During what should have been the rainy season—the monsoon did not break till the last day of July—I kept up a fruitless search and it was not till towards the end of November that I met with any success. Up to the end of September the rains had been so poor that no Charophytes appeared and by the end of October the most likely spots were still full of rice and choked with rainy season vegetation.

My first gathering when at last Charophytes appeared again was an interesting one, *viz.*, the capitate form of *Nitella dispersa* that I had previously found at Saharanpur. I have recently had both forms from Benares where Parsotam who has enthusiastically assisted me for twenty-five years in my various Natural History pursuits is still collecting these plants for me. In addition to the species already mentioned I found *C. corallina* and at Christmas, in a pool by the Ganges in the Etah District. I came across *C. Wallichii* of which I have only one record from Bareilly.

During this cold weather, Railway borrowpits were almost the only suitable pieces of water available, the good spots I had marked down the previous March being all dried up by mid-January. I continued to find *C. contraria* very common during this month.

Preparations for my final departure left me little leisure for Charophytes but my last hunt—on February 16th—when chancing to search a roadside pond I noticed round the margins something that was quite new to me. It was a very distinct looking *Nitella* growing in small closely-set round clumps about six inches high, being no taller or more spread-out even in deeper water. It proved to be *N. Stuartii,* a monœcious species characterised by one-celled dactyls and twice-furcate branchlets. This plant puzzled me a good deal at first owing to the excessive number of branchlets at the stem whorls and its much-tufted character. It reminded one rather of a *Tolypella.* I have attempted to give an idea of the plant in the accompanying much too diagrammatic sketch.

There are usually two branches to a node in a *Nitella* but here there are often at least four and at a lower whorl as many as ten or more usually sterile branchlets. At the upper whorls the plant is decidedly heteroclemous, *i.e.,* two sets of branchlets—the longer primary and the shorter secondary. The congested masses at the bases of the upper whorls consist of young branches. In the case of fertile branchlets the secondary rays, usually about 5-6 in number, are often much shortened producing a tufted appearance. The one-celled dactyls, usually 4-6 in number, are more or less equal in length: the points are decidedly acuminate but the apex is not very attenuated. The dactyl often has a tendency to be somewhat narrowed again at the base.

The plant fruits freely at both branchlet-nodes, the oogonia being clustered. The oospore is of a rich brown colour, c. 250 μ

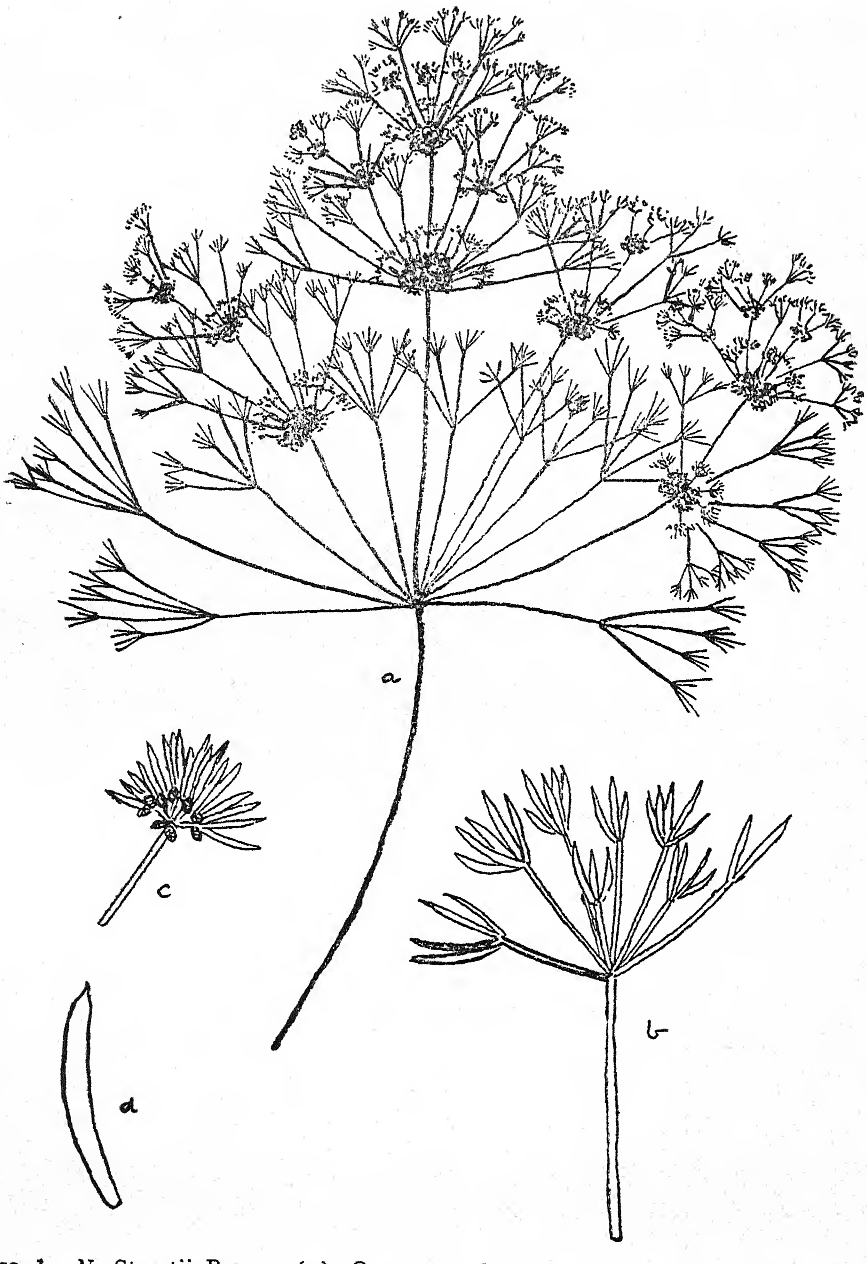


FIG. 1.—*N. Stuartii* Braun : (*a*) One stem of plant, nat size ; (*b*) sterile branchlet. × c. $1\frac{1}{2}$; (*c*) small fertile branchlet. × c. 3; (*d*) a dactyl. × c. 8.

long and 200 μ broad, the membrane being clearly though somewhat finely reticulate. My gatherings were in an advanced state of development and rather brittle from lime incrustation: ripe fruit was very plentiful but antheridia were not easy to find.

This is the first record of this species from India. I have recently had it also from Benares. It was originally described from Tasmania and has also been found in New Zealand, Australia (Queensland) and Japan.

The recent deaths of Mr. Groves who rendered so much help in the investigation of Indian Charophytes and of Canon Bullock-Webster (joint author of that excellent monograph, British Charophyta) who devoted special attention to oospores and their membrane decoration, are grievous losses to the study of this group.

Specimens, especially in fluid, addressed to me c/o Messrs. Grindlay & Co., 54 Parliament St. London, S.W. 1., will be most welcome at any time.

Summary

Records from Bareilly, U.P., of four species of *Nitella,* one of *Tolypella* and six of *Chara* including a new one for India, *viz.,* *N. Stuartii* Braun.

ON THE CYTOLOGICAL EVIDENCE FOR AN ALTERNATION OF GENERATIONS IN *ENTEROMORPHA*

(PRELIMINARY NOTE)

BY

K. R. Ramanathan, B.Sc. (Hons.)

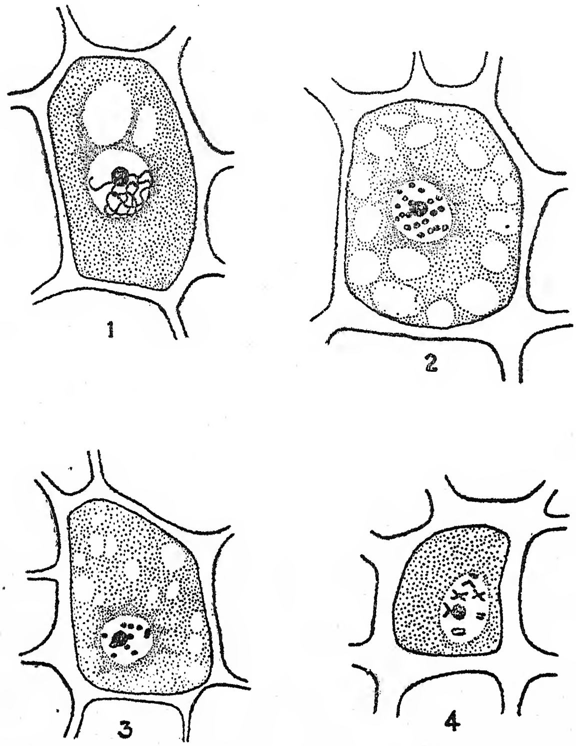
Research Student, University Botany Laboratory, Madras

Received for publication on 28th November, 1935

Recently Foyn (1929, 1934) has shown by his cultural as well as by his cytological investigations that there is a regular alternation of a haploid sexual and a diploid asexual generation in *Ulva*. But so far nothing is known *cytologically* regarding the alternation of generations in the allied genus *Enteromorpha,* though the probability of an alternation quite similar to that of *Ulva* in *Enteromorpha* also was suggested by Hartmann (1929) and Bliding (1933) from observations based on their cultural study of the alga.

The author, taking advantage of the profuse and common occurrence of *Enteromorpha compressa* (L.) Grev. in the Cooum estuary at Madras, undertook a detailed investigation of its cytology and life-history. The alga was collected during different parts of the year and the individual plants were kept growing separately in several culture dishes. Swarm-spores were formed in all of them, but only gametes (biciliate) were formed in some plants, while in others only zoospores (quadriciliate). The plants producing gametes when fixed and examined were found to be all haploid with 10 as their chromosome number (Text-fig. 3), while those plants producing zoospores were found to be all diploid with 20 as their chromosome number (Text-fig. 4). Prior to the formation of zoospores, reduction division was observed with the characteristic synizetic (Text-fig. 1, Pl. V, B, C) and diakinetic stages (Text-fig. 4, Pl. V. A.). The gametes formed by the haploid plants fused in pairs, the conjugating gametes showing all the transition stages from isogamy to anisogamy. Further, the gametes from the same plant never fused with one another, fusion taking place only when gametes from two different plants were brought together. Evidence was also available to show that there was a differentiation of sex among the haploid sexual plants. The zygotes formed by the fusion of the gametes germinated without resting and the plants formed from them were reared

to full grown ones in culture solutions. These plants when mature produced only zoospores, but no gametes. The zoospores, after liberation, swarmed for some time, settled down and began to germinate. The germlings formed by them were cultivated in the laboratory, as in the case of the zygotes, to full grown plants. These plants when mature formed only gametes, which as before fused in pairs and formed zygotes, and the life-history as sketched above was repeated.



Text-figs. 1—4. *Enteromorpha compressa* (L.) Grev.

Text.-fig. 1. Synizesis in the first nuclear division of the cell forming zoospores. Text-fig. 2. Metaphase plate of somatic mitosis in the diploid plant showing 20 chromosomes. Text-fig. 3. Metaphase plate of somatic mitosis in the haploid plant showing 10 chromosomes. Text-fig. 4. Diakinesis in the first nuclear division of the cell forming zoospores, showing the 10 bivalent chromosomes. All figs. ×1600.

Thus the author's cultural observations on *Enteromorpha compressa* (L.) Grev., agree in all details with those of Hartmann (1929) and of Bliding (1933) made on the several species of *Enteromorpha* studied by them. And the results of the present

cytological study, *viz.*, that the gamete-producing plants are all haploid and the zoospore-producing plants are all diploid, the reduction division taking place just before zoospore formation, fully confirm the conclusions arrived at by Hartmann and Bliding regarding the occurrence of an alternation of generations in *Enteromorpha* from their cultural observations.

The author wishes to express his indebtedness to Prof. M. O. P. Iyengar, for his guidance and help throughout the course of this work.

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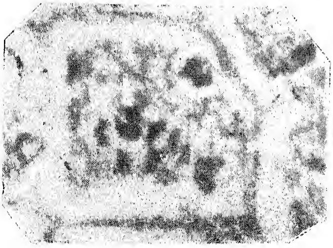
Explanation of Plate V

Enteromorpha compressa (L.) Grev.

A. Photomicrograph showing diakinesis. ×2300.

B. Photomicrograph showing synizesis. ×2300.

C. Photomicrograph showing a large number of cells with nuclei in synizetic stage. ×1150.



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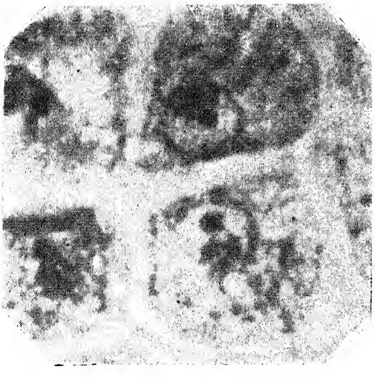

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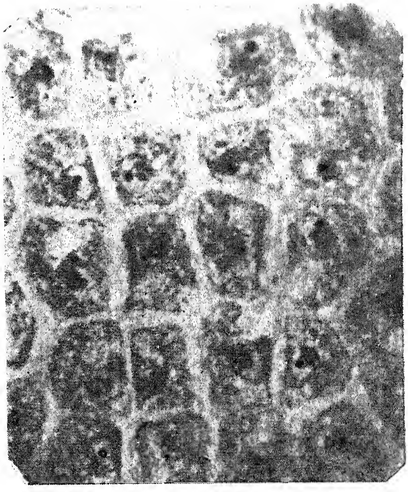


C

K. R. RAMANATHAN—*ENTEROMORPHA COMPRESSA* (L.) GREV.

THE MECHANISM OF THE BURSTING OF THE FRUITS OF *IMPATIENS BALSAMINA* LINN.

BY

P. Parija, M.A.

AND

P. Mallik, M.Sc.

Ravenshaw College, Cuttack

Received for publication on 1st February, 1935

Introduction

It is generally believed that the cause of the bursting of the balsam fruits is turgescence in the cells of the fruit-wall. The capsules have five carpels. The sutures are in longitudinal furrows. The walls consist of three zones of cells, the middle one being of large turgid cells as seen in transverse sections. When ripe, spontaneously, or if touched, the five lanceolate carpels separate suddenly and roll up inwardly, throwing the seeds out to some distance. It is an advantage that the seeds are borne at the basal end of the capsule.

With a view to further probing into the mechanism of the bursting of the balsam fruits, this investigation was undertaken.

Materials and Method

Fruits at various stages of maturity were collected and fixed in absolute alcohol. Fixation in chrome-acetic acid also gave good results.

Microtome and hand sections were cut and stained in various staining solutions. Safranin was advantageously used and very good results were obtained after 24 hours in the stain. A distinct radial zone (T.Z. in Fig. 1) was noticed in the site of the furrows. This layer was stained red as the vascular elements in the inner walls of the fruits (X.Y. in Fig. 1). The cells in these parts were devoid of chloroplasts and the cell-walls were thick. Distinct stratifications were noticed (Fig. 1) and it was found that the zone was 4-cells deep.

Safranin stain proved that the cell-walls in this zone are suberised. This was confirmed by treating the section with strong sulphuric acid as follows:—

A transverse section (not very thin) was mounted in water and examined to find the suberised layer. They were darker than the rest. The superfluous water was then removed by blotting paper and a drop of concentrated sulphuric acid was put on the section which was now covered with a cover slip. It was seen that the

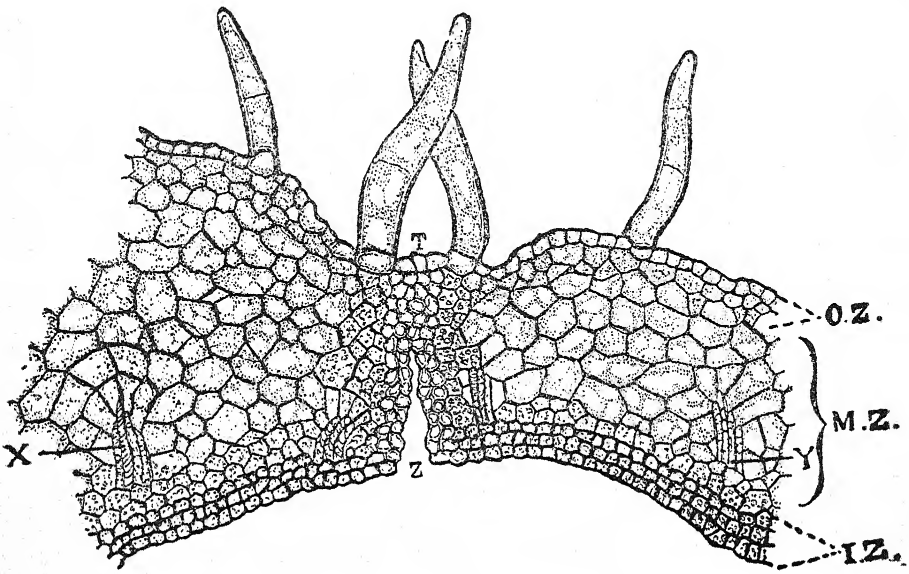


Fig. 1: Camera Lucida drawing of a section of fully matured pericarp showing the site of rupture. T. Z.—transverse zone of suberised plate. O. Z.—outer zone. M. Z.—middle zone; I. Z.—inner zone. ×50.

walls of the turgid cells of the middle zone began to swell gradually and at last dissolved. But the darker radial plates in the site of the furrows became clearer but otherwise remained in tact.

To find the line of cleavage of carpels, half-ripe and fully-ripe fruits were fixed in alcohol. Stained microtome sections were examined and it was found that the carpels always burst along a distinct line just in the middle of the plates of suberised cells, leaving two rows of cells on either side (Fig. 1).

The osmotic strength of the cell-sap increases as the fruits mature. In very young fruits the strength of the sap was found to be isotonic with 0·43 per cent. to 0·7 per cent. solution of KNO_3 and in ripe fruits it was found to be nearly 2·5 per cent. The strength of the sap in the cells of the fully matured fruits increases as one goes from the inner to the outer surface of the carpels. The

innermost cells of the middle zone had a sap of lesser concentration (2·1 per cent.) while the outermost cells had more concentrated cell-sap (2·5 per cent.).

The strength of the sap also varies as the temperature during the day varies. When half-ripe fruits were cut and examined for the strength of the sap during the day, the following results were obtained:—

(i) at 7-30 a.m. (Temp. 82°·4F) the sap strength was to be isotonic with 1·2 per cent. solution of KNO_3.

(ii) at 2 p.m. (Temp. 89°F)—isotonic with 1·43 per cent. KNO_3.

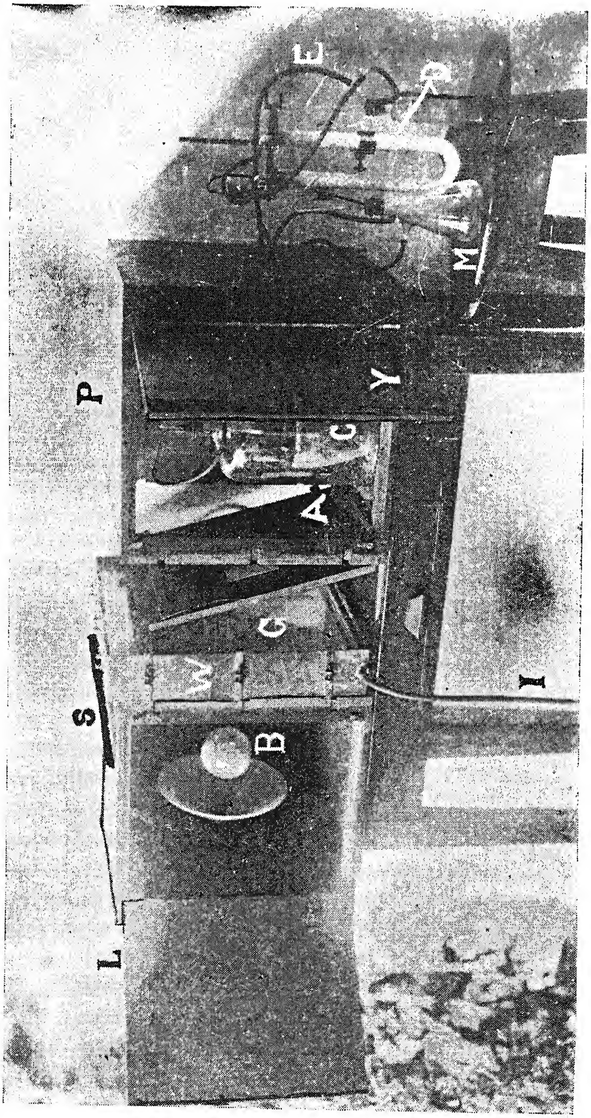
(iii) at 7 p.m. (Temp. 84°F.)—isotonic with 1·25 per cent. KNO_3.

Thus it is clear that the greater osmotic strength of the outer cells of the pericarp of the ripe fruits brings about greater turgidity of these cells. In consequence a tension between the inner layer of cells and the outer layer must be coming into existence as the ripening progresses, resulting in a tendency in the carpels to roll in. This tendency in young and half-ripe fruits is presumably resisted by the unsuberised sutures. When the sutures become suberised this resistance disappears and they get ruptured on slightest disturbance and the carpels roll in.

Summary

The mechanism of the bursting of the balsam fruits were investigated. Sections of half-ripe and fully-ripe fruits were cut and stained for 24 hours with safranin. Osmotic strength of the cell-sap at various stages of maturity were studied.

It was found that turgidity is not the only cause of bursting. It is helped by the suberisation of the cell-wall at the suture of the adjoining carpels.



P. PARIJA *AND* P. MALLIK.—*APPARATUS FOR EXPERIMENTS ON CUTICLE FORMATION*

THE FORMATION OF CUTICLE IN RELATION TO EXTERNAL CONDITIONS

BY

P. PARIJA, M.A.,

AND

P. MALLIK, M.SC.

Ravenshaw College, Cuttack

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Contents

Introduction

All the tissues of a differential plant body are derived from meristematic cells, chemical changes proceeding both in protoplast and wall as these cells vacuolate and increase in size and pass over into various forms that characterise the adult tissue. When these changes are proceeding in the tissues arising from the apical meristem of the angiosperm shoot, one of the earliest result is the formation of the cuticle over the surface of the shoot (1). Besides other differentiations, this cuticularisation is markedly observed in plants adapted to dry climates and there are various ways either to check excessive transpiration or to economise loss of

water. Among other things, such as sunken stomata, hairy outgrowth, rolling of leaves into a tube with stomatal surface inside, blocking of stomata by wax or resins, shedding of leaves, etc., a thick cuticle covered by a deposit of wax to reflect light is indispensible to diminish epidermal transpiration.

According to Priestley (2) three fundamental facts are associated with the formation of cuticle:

(i) In the process of synthesis the meristematic protoplast gives out fatty substances,

(ii) these fatty substances migrate to plasmatic interfaces during the process of vacuolation and differentiation, and

(iii) ultimately pass into or along the walls till they reach the surface of the shoot where by process of oxidation and condensation they form a layer.

These facts should as a matter of fact be true in all plants right from Algae to Angiosperms, but we find that cuticle is absent in most of the lower plants. It appears in higher plants in response to certain external conditions as well as the complexity of plant organs.

Thus Lee and Priestley say (1, p. 536):—"External conditions will obviously play a large part in determining the nature and extent of cuticular deposit if these are the result of a chain of processes involving migrations of fatty substances on to or along the plantwall and their subsequent oxidation and condensation at the surface in contact with the air."

In the present paper we have endeavoured to study the effect, if any, of external environmental factors, such as light of different wave-lengths, humidity, temperature, etc.

Experimental Materials

Small plants (*Ficus religiosa*) were collected and planted in pots. For each experiment different sets were used.

APPARATUS

An apparatus (Pl. VI) was designed for the purpose of conducting the experiment under controlled conditions.

Description.—Two glass plates were fitted in a brass frame 2″ apart, and parallel to one another. The space enclosed by the plates and the brass frame was made water-tight. Two brass tubes, one at the bottom and one at the top, connected the inside of the chamber with outside and served as inlet and outlet for water. The brass frame holding the plates projected both ways a bit outward at right angles to the plane of the plates. These constituted the *Water-screen* of the figure.

Two wooden chambers (2′ × 2′ × 2′) could be fitted in on two sides of the water-screen. Frontal sides of the chamber were on hinges and served as doors. When these were opened the

arrangements inside the chambers could be manipulated without disturbing anything. The left-hand chamber was used as a "Light-chamber" by fitting up a high candle power bulb and making necessary electrical connections on the extreme left side which was made up of two walls 1″ apart. Some holes on these two walls were made in such a way that no light could come out from the chamber but air can get in through these and come out of the chamber through the shutter on the upper side. Entrances for rubber tubings were made on the extreme right side of the other chamber ("Plant-chamber").

An adapter was used to hold the Wratten filters in position when light of different wave-lengths were intended for experimental purposes.

Experiments

EFFECT OF HUMIDITY AND LIGHT. (Exp. No. 1A)

Two pot plants were taken. One of them was covered with a belljar and made air-tight. Two tubes passed through the cork at the top of the belljar. Inside the belljar, containing the "Control-plant" humidity was kept constant by passing an air current saturated with moisture. This was done by bubbling air through water and circulating this air in the belljar. The upper portion of the other pot plant was sealed in a round-bottomed thin-walled flask. An air current dried by passing it through concentrated H_2SO_4 and a series of $CaCl_2$ tubes was circulated in the enclosed part of the flask containing the "Experimental-plant." The last $CaCl_2$ tube was occasionally weighed to find if there was any increase in weight, but the weight remained almost constant or showed negligible difference, indicating that the air current was made perfectly moisture-free before it entered the round-bottomed flask containing the "Experimental-plant."

The leaves (the cuticle of which were to be measured) of the "Control" and "Experimental" plants were fully grown when the experiment was started. Measurements of the cuticle were taken before the experiment for leaves of both the plants by taking sections from portions of the leaves. The experiment was conducted for a week under ordinary conditions of day and night. Transverse sections of the marked leaves from both the plants were cut, stained and mounted in glycerine and drawings were made (Figs. 1 to 3).

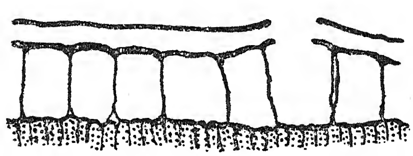

Fig. 1: T. S. of the leaf which was exposed to alternate daylight and artificial light (Exp. 3. a)-thickness of the cuticle 2·84. ×200.

The same experiment was repeated (Exp. No. 1B), this time for a fortnight. The leaves (to be experimented) were of the same age, the age being counted from the opening of the leaves. After the experiment thickness of the cuticle was measured in both and it was found that the thickness varied with the number of days.

EFFECT OF HUMIDITY ALONE

The above experiments were under ordinary conditions of day and night. With the help of the wooden chambers and water-screen, the effect of heat and light were eliminated (Exp. No. 2). Two well watered plants were kept in the plant chamber, one in moist, and the other in moisture-free atmosphere. The plants remained in the dark. The circulating water in the water-screen kept the temperature in the plant chamber constant at 80°F., outside temperature being 83°F. After a fortnight in this condition the marked leaves showed no improvement in the thickness of the cuticle, the thickness before and after the experiment being the same (1·2 μ).

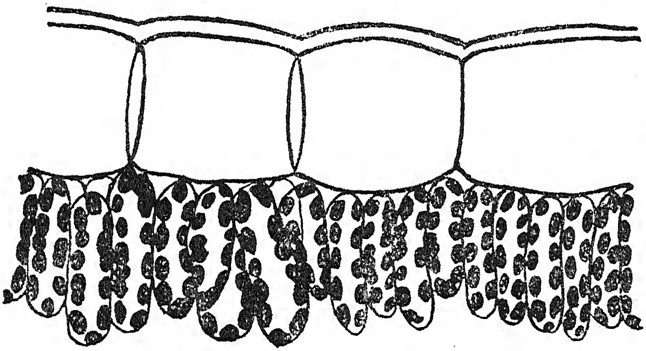

Fig. 2: T. S. of the leaf-exposed to alternate daylight and artificial light as in the previous experiment but the heat rays were cut off here (Exp. 3. b)-thickness of the cuticle 1·99. $\times$ 500.

So dryness alone has no effect on the formation of cuticle, but dryness coupled with light induces cuticle formation.

EFFECT OF LIGHT

(*a*) *Alternate day light and artificial light*

Here (Exp. No. 3A) the "Control" plant was kept under constant humid condition and the "Experimental" plant in moisture-free atmosphere. Both of them were exposed to a light from a 200 c.p. bulb at a distance of 40 cm. at night. The arrangements are shown in the figure. In the day time the conditions remained the same except that the artificial electric light was switched off. Record of temperature throughout the experiment was kept with the help of a thermograph which showed almost constant temperature (90°F.). The experiment was conducted for a week.

The marked leaves of the experimental plant showed much improvement in the thickness of the cuticle (2·84 μ against 0 μ), proving that the thickness varied with the duration of exposure to light.

(*b*) *Alternate day light and artificial light without heat rays*

As direct lighting was likely to raise the temperature of the chamber, heat rays were cut off by interposing the water-screen between the source of light and the plant chamber (Exp. No. 3B). Temperature came down to 80°F. After a week the thickness of the cuticle was found to be less than the corresponding thickness in the previous experiment (1·99 μ against 2·84 μ).

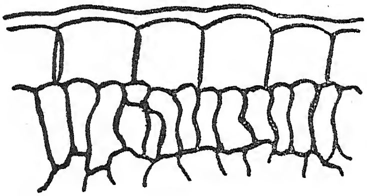

Fig. 3: T. S. of the control leaf, exposed to continuous artificial light with 100% humidity and without heat rays. (Exp. 3. c). No increase in the thickness of the cuticle was noticed. × 200.

(*c*) *Continuous artificial light without heat rays*

With the help of the apparatus already described, the sunlight was cut off from the plant chamber where besides the "Control" and "Experimental" plants a third plant was kept. As before the control plant was in a moisture-saturated atmosphere whereas the experimental plant was in moisture-free air. The whole arrangement is shown in the figure. All the three plants were exposed to continuous light from the 200 c.p. bulb for a fortnight. Heat rays were cut off from the plant chamber by the water-screen in which a continuous water-current was made to circulate. The temperature of the plant chamber remained constant at 90°F. (room-temperature being 94°F.). The plants were watered from time to time.

The results were: (i) the leaves in dry atmosphere had the thickest cuticle (1·99 μ against 1·42 μ)

(ii) the leaves in ordinary air had less thick cuticle (1·05 μ against 0·85 μ).

(iii) while the leaves in moist atmosphere did not develop any more cuticle than what they started with (1·42 μ).

After a fortnight the leaves of the control plant had a corrugated appearance, wavy margins, larger surface and were curling at the tips. They were more intensly green, softer and glossier than the leaves of the experimental plant. Production of new leaves went on as usual. The leaves of the experimental plants were smaller in area and they had a dull appearance. They were tough

to the touch and seemed thicker. Production of new leaves was arrested. The general appearance of the plant plainly showed that it had more power of resistance against abnormal conditions. The control plant had lost that power as it was seen that the leaves began to show sign of wilting on the first day the plant was brought out into ordinary atmosphere. But afterwards, it came round very slowly and became adapted to the ordinary conditions of environments.

The point of interest of this experiment (Exp. No. 3) is that during the first part no arrangement was made to cut off the heating effect of light so that the temperature rose up to 90°F., but when the water-screen was put in the path of rays of light, the temperature came down to 80°F., the intensity of light being very slightly affected (only 1 to 2 per cent), as proved by actual photometric measurements.

The other factors having remained the same, when the temperature was lowered by 10°F., the thickness of the cuticle also became less. This clearly proves that in conjunction with light heat has got some influence on the formation of cuticle.

EFFECT OF HEAT

The bulb during this experiment (Exp. No. 4A) was covered with a light-proof metal box and the whole arrangement was kept in the dark-room for a week. When the cuticle was measured it showed no increase in thickness (see table of results).

This was confirmed later on by conducting the experiment (Exp. No. 4B) in the wooden chambers. Arrangements were the same as in the light experiments excepting that instead of the water-screen a thick black cloth was placed in its position to cut off light rays while allowing heat rays through. The temperature rose 20°F. and it remained near about 100°F. as against 80°F. outside.

After a week in this condition the plants were taken out and the thickness of the cuticle of the leaves were measured. They did not show any improvement ($1 \cdot 2\ \mu$ before and after the experiment). This clearly shows that heat without light has no influence on cuticle formation.

Thus in darkness, temperature and dryness, either singly or jointly do not lead to cuticle formation.

EFFECT OF LIGHT OF DIFFERENT WAVE-LENGTHS

(*a*) *Red Rays.*

The experiment (Exp. No. 5A) was first started in the dark room. The plant was kept in ordinary atmosphere. The bulb was at a distance of 40 cm. from the plant. The heat rays were cut off by the water-screen. One of the branches of the plant was lighted by the rays passing through a Wratten Filter (red) while another was in the ordinary light from the bulb. The experiment lasted for a week. The thickness of the cuticle was $0\ \mu$ before and after the experiment.

The experiment was repeated, this time in the wooden chambers. The adapter for holding the Wratten Filters was used. A week after, the leaves had the same thickness of the cuticle ($0\,\mu$)—no matter whether they were taken from the humid or dry part of the arrangement.

(*b*) ***Blue Rays.***

The red filters were replaced by blue ones (Exp. No. 5B). After the experimental period (one week), the leaves in the dry atmosphere had a thicker cuticle ($1{\cdot}72\,\mu$) than those in moist air ($1{\cdot}42\mu$). Both had the same thickness ($1{\cdot}42\mu$) when the experiment was started.

Results

No. and duration of experiment.	Plant.	Factors acting on leaves: Nature of light	Tempe-rature.	Humi-dity.	Thickness of cuticle in μ: Before	After
1. (*a*) 7 days.	'Con.'	Intermittent (sun-light and darkness alternately).	80°F	100%	1·0	1·0
	'Exp.'		,,	0%	1·0	1·99
(*b*) 15 days.	'Con.'		,,	100%	0·0	0·0
	'Exp.'		,,	0%	0·0	2·27
2. 15 days.	'Con.'	Darkness	80°F	100%	1·2	1·2
	'Exp.'			0%	1·2	1·2
3. (*a*)	'Con.'	Alternate daylight and artificial light.	90°F	100%	0·0	0·0
	'Exp.'			0%	0·0	2·84
(*b*) 15 days.	'Con.'	Do. without heat rays.	80°F	100%	0·0	0·0
	'Exp.'			0%	0·0	1·986
(*c*)	'Con.'	Continuous artificial light without heat rays.	90°F	100%	1·419	1·419
	'Exp.'			0%	1·419	1·986
	'Ord.'			72%	0·851	1·055
4. (*a*) 7 days.	'Con.'	No light	90°F	100%	1·2	1·2
	'Exp.'			0%	1·2	1·2
(*b*)	'Con.'		100°F	100%	1.2	1·2
	'Exp.'			0%	1·2	1·2
5. (*a*)	'Con.'	White ..	90°F	67%	0·0	0·56
	'Exp.'	Red ..	,,	67%	0·0	0·0
(*b*) 7 days.	'Con.'	Do. ..	,,	100%	0·0	0·0
	'Exp.'	Do. ..	,,	0%	0·0	0·0
(*c*)	'Con.'	Blue ..	,,	100	1·419	1·419
	'Exp.'	Do. ..	,,	0%	1·419	1·722

Summary

Experiments on the influence of light, humidity and temperature on the formation of cuticle are described. It is seen that:—

1. Not dryness alone but dryness coupled with light induces cuticle formation.

2. The thickness of the cuticle varies with the degree of dryness and with the intensity of light.

3. Red rays are ineffective while blue rays induce cuticle formation.

4. Heat alone apart from light has no influence but heat coupled with light induces cuticle formation to some extent.

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Explanation of Plate VI

Apparatus for experiments on cuticle formation.

L — light-chamber with a 200 c. p. bulb (B) and a shutte.

P — plant-chamber, (Y)-the frontal loor is on hinges. The 'Control' plant (C) is only seen, the 'Experimental' plant is behind the control plant.

W — water-screen, (G)-one of the glass-plates, (I)-the inlet tube.

A — adapter for holding the Wratten Filters in position.

D — apparatus for drying air, the extreme right bottle contains strong H_2SO_4, and the other one contains anhydrous $CaCl_2$.

M — flask with water through which air is bubbled before it is made to circulate in the belljar containing the 'Control' plant (C).

E — exhaust pump.

STUDIES ON CAPPARIDACEAE.

I. THE EMBRYO-SAC OF *MAERUA ARENARIA* FORSK.*

BY

V. S. Rao

Benares Hindu University

Received on 7th June, 1934

Introduction

Capparidaceae is one of those few families upon the life-histories of which absolutely no work†, has hitherto been done, although cytological work has been carried out on a few genera. Schürhoff (6) mentions only two such — one by Tischler (8) upon *Cleome paradoxa* and the other by Taylor (7) upon *Cleome spinosa*. Schnarf (5) in his recent book upon the Embryology of Angiosperms gives for the whole of Capparidaceae only the work of Guignard (1) on *Polanisia graveolens*.

Apart from these, there are other researches also upon the cytology of some genera of this family, for instance, Schiller (4) working upon *Capparis* and Janaki Ammal (3) upon *Cleome*. A complete list of the cytological literature upon the family is out of place here.

The present investigation deals only with the megasporogenesis and the development of the female gamtophyte of *Maerua arenaria,* as the fixative used has not preserved the pollen mother cells in a suitable condition for cytological study and fresh or more material could not be obtained at the time. It is hoped that at a future date it will be possible to study the other phases also of the life-history. Investigations upon the other genera of the family are in progress, and will be published in due course.

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* The work has been partly aided financially by Prof. N. K. Tiwary.

† After the manuscript of this paper had been completed and sent to the press, investigations of some other plants of this family have been published by Mauritzon. (Arkiv fur Botanik 26, 1934.)

Material and Methods

Floral stages of *Maerua arenaria* fixed in formalin-acetic-alcohol were kindly given by Prof. N. K. Tiwary for investigation. The material was collected at the request of Prof. Tiwary by Dr. Maheshwari at Agra. Before dehydration the material was thoroughly washed in alcohol to remove every trace of formalin and acetic acid. Xylol was used as the clearing agent and the material was imbedded in paraffin. Sections were cut 8 to 10 microns thick and were stained with iron-alum-haematoxylin using safranin as a counter stain. A combination of safranin and gentian violet was also tried but this did not give satisfactory results.

Megasporogenesis

The primary archesporial cell (Fig. 1) is hypodermal in position and this cuts off a primary parietal cell by a periclinal wall. The first division in the primary parietal cell is always periclinal and most commonly by two such divisions a row of three parietal cells (Fig. 2) is formed, in the top-most cell of which division later takes place by an anticlinal wall (Fig. 3). This order of division is most common. The parietal tissue may develop further or it may stop at this stage. The sporogenous cell (Fig. 3) becomes the megaspore mother cell directly, enlarging considerably during the process.

By two successive divisions a linear tetrad of megaspores (Fig. 4) is formed of which the lower-most functions and the other three degenerate (Fig. 5). The degeneration of the non-functioning megaspores occurs so early and so quickly that even in the two-nucleate stage of the embryo-sac mostly not a trace of them remains. The degeneration begins with the top-most megaspore and extends downwards.

Development of the Embryo-sac

The functioning megaspore enlarges in size and its nucleus divides. The two daughter nuclei go to opposite poles (Fig. 6). Each nucleus then divides twice successively resulting in an 8-nucleate embryo-sac (Fig. 8). The young embryo-sac is nearly 5 or 6 times as long as it is broad and from the 4-nucleate stage (Fig. 7) onwards is slightly curved.

In the 8-nucleate stage cytoplasm accumulates round all the nuclei (Fig. 8) but only three at each end of the embryo-sac form definite cells producing the usual egg-apparatus at the micropylar and the antipodals at the chalazal end. The embryo-sac during its further growth increases more in width than in length in such a way that it becomes straight losing its former curvature.

The Synergids

The mature synergids (Figs. 9-11) are greatly elongated, the length being five times or even more than the width. They are flask-shaped being broad at the base which merges into a narrow elongated and blunt neck. Each synergid has a filiform apparatus filling almost the whole of the neck. The nucleus is always situated in the broad basal region.

The Egg

The egg cell is placed at the base of the synergids and is more or less spherical (Figs. 9-11) with a small stumpy beak-like prolongation towards the micropylar side. The cytoplasm is finely vacuolate. Although in one embryo-sac (Fig. 10) the egg cell extends almost to the top of the embryo-sac like the synergids, the most common condition for it is to be situated at the base of the synergids (Figs. 9 and 11).

Formation of the Secondary Nucleus

After the completion of the 8-nucleate stage one nucleus from the micropylar side and one from the chalazal side advance towards the centre (Fig. 9) and fuse in close proximity to the egg-cell to form the secondary nucleus (Fig. 11). These polar nuclei are larger than even the egg nucleus.

The Antipodals

The antipodals attain a very large size occupying the whole lower half of the embryo-sac (Figs. 9 to 11). Each antipodal throughout its life-history is uninucleate and attains a somewhat hemispherical shape in comparison with the size of the cell, the nucleus being rather small.

The position of the three antipodals in relation to one another is variable, but usually two of them lie side by side and the other lies above these (Fig. 9). Sometimes the sizes of the nuclei and the antipodal cells are unequal. As growth proceeds the antipodals lose their hemispherical shape and become elongatd but still occupy completely the lower half of the embryo-sac (Fig. 11).

At about the time of fertilization the antipodals completely degenerate.

Summary

1. The primary archesporial cell is hypodermal in position and parietal tissue is developed.

2. A linear tetrad is formed by the megaspore-mother cell and the lowest megaspore functions.

3. The synergids are long and narrow and are capped by a filiform apparatus.

4. The two polar nuclei which fuse to form the secondary nucleus are larger than even the egg nucleus.

5. The antipodals are large, uninucleate and occupy the lower half of the embryo-sac.

Here I take the opportunity of expressing my gratitude to Prof. N. K. Tiwary for his kind and able guidance throughout the course of the investigation and also for kindly going through the manuscript. I also thank Dr. Y. Bharadwaja for permitting me to work in the laboratory and for giving me all the facilities.

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Explanation of Plate VII

All figures are camera lucida drawings, and are not of equal magnification.

Fig. 1. Hypodermal archesporial cell. ×500.

Fig. 2. The sporogenous cell, and three parietal cells in a row. ×500.

Fig. 3. Similar to Fig. 2, but after the top-most parietal cell has divided auticlinally. ×500.

Fig. 4. Linear tetrad. ×600.

Fig. 5. Linear tetrad, with the lower-most megaspore functioning, and the upper three degenerating. ×600.

Fig. 6. Two-nucleate embryo-sac. ×500

Fig. 7. Four-nucleate embryo-sac. ×400.

Fig. 8. Young 8-nucleate embryo-sac. ×400.

Fig. 9. Almost mature embryo-sac, before the degeneration of the antipodals, showing nearly spherical egg. (Drawn from more than one successive sections.)

Fig. 10. Similar, but showing a flask-shaped egg. (From more than one successive sections.)

Fig. 11. Mature embryo-sac after the fusion of the secondary nucleus and when the antipodals have almost degenerated. (From more than one successive sections.)

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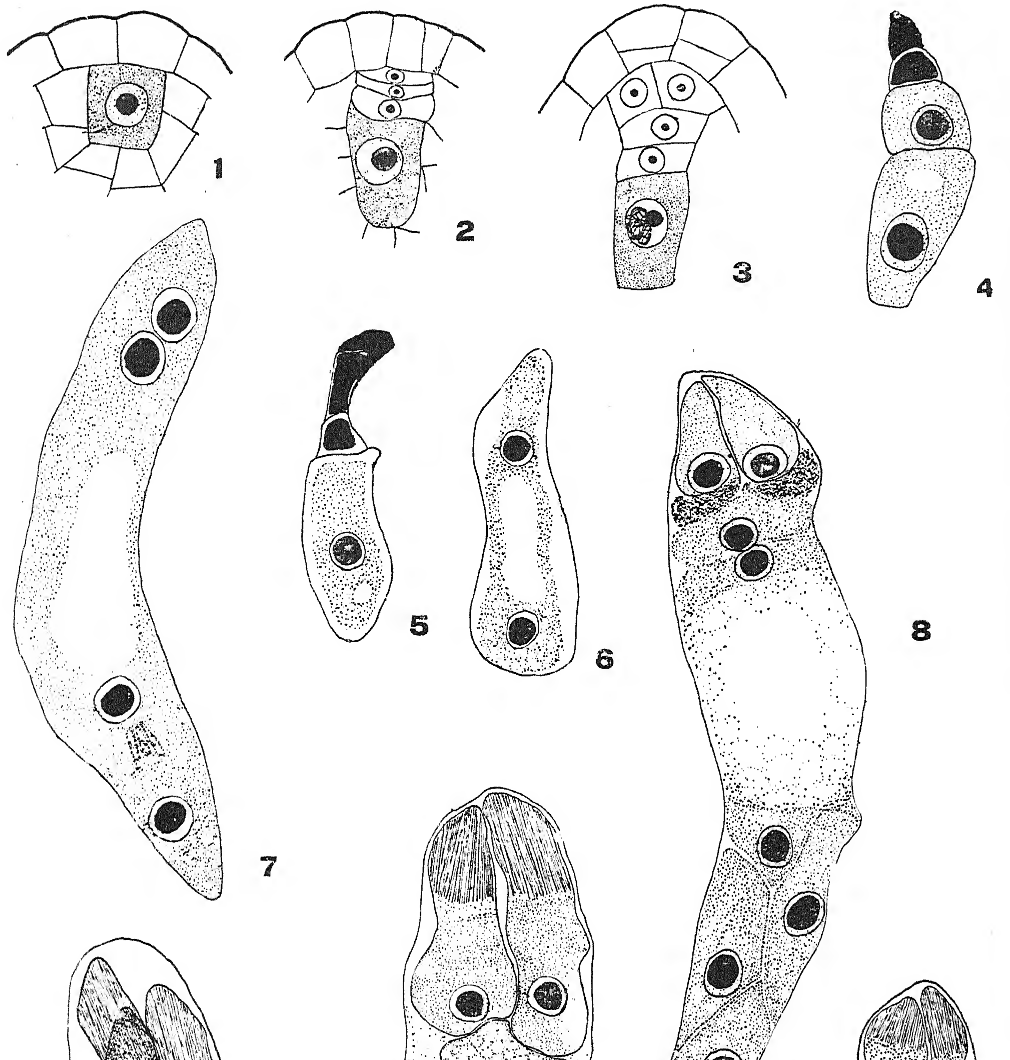


V. S. RAO—*MAERUA ARENARIA* FORSK.

ANATOMY OF THE FLOWERS OF *STELLERA CHAMAEJASME* LINN.

BY

A. C. Joshi

Department of Botany, Benares Hindu University

Received for publication on 6th January, 1934

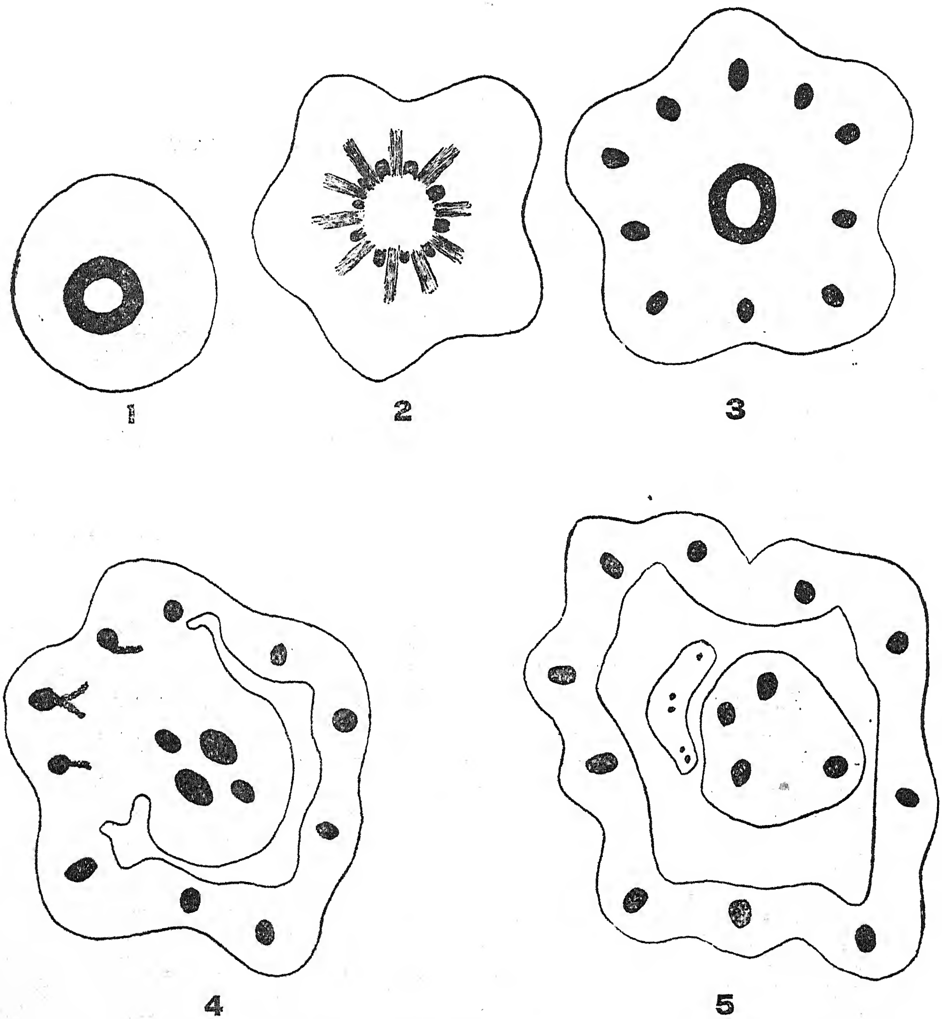
The gynaecium in the family Thymelæaceæ, except in the genus *Aquilaria* and its allies, is usually considered to be composed of only a single carpel. A study of the floral anatomy of *Stellera Chamaejasme* Linn., however, leads to a different interpretation. Such a study also helps to clear the morphology of the disk-scales in the genus.

Stellera Chamaejasme is an inhabitant of Himalayas, Tibet, N. and Central Asia. The material for the present investigation was collected from Dochen in Central Tibet at a height of about 14,000 ft. above sea-level by the late Professor S. R. Kashyap.

External Morphology

Flowers of *Stellera Chamaejasme* are borne in terminal sessile involucrate heads. They are usually 4- or 5-merous, but Kashyap (10) has figured a 6-merous flower also. The flowers that the writer examined were all pentamerous. There is a short pedicel. The perianth-tube is cylindric. Its upper part is deciduous and separates off in a circum-sessile manner from the lower part and falls off. The lower part remains persistent round the ovary even in the fruit. The perianth-tube ends at the top in 4-6 short oblong lobes. Scales are absent from the throat of the perianth-tube. Stamens are twice the number of the perianth-lobes, in two series, one slightly above the other. The disk is produced on one side into one or two linear or lanceolate blades. The earlier authors had noticed the presence of only one such scale, but Kashyap (10) recently described that specimens from Western Himalayas show only a single scale, while those from Central Tibet (Dochen) show the presence of two disk scales. In the writer's material, which had come from the latter place, some flowers were found to show two scales, others only a single scale. The flowers microtomed for the present study possessed only a single disk-scale. The ovary is shortly stalked,

1-celled, possesses a solitary anatropous ovule pendulous from the top of the cell, and bears a short terminal style. Fruit is an indehiscent achene included in the base of the perianth.



Text-figs. 1-5: *Stellera Chamaejasme.* A series of transverse sections of the flower from below upwards; Fig. 1: transverse section of the thalamus showing the vascular tissue in the form of a ring; Fig. 2: the origin of the perianth traces; Fig. 3: the perianth traces are at the periphery and the remaining vascular tissue in the centre is again forming a complete ring; Fig. 4: shows the separation of the perianth-tube, origin of the disk-scale traces, and the breaking up of the vascular tissue in the centre into four bundles supplying the gynaecium; Fig. 5: shows the complete separation of the perianth-tube and the disk-scale from the gynophore. The Vascular tissue in all the figures is represented in black. $\times$ 90.

Internal Anatomy

(*a*) *Pedicel.*—The pedicel of the flower receives a single collateral bundle from the axis of the inflorescence. At the base of the pedicel, it is bow-shaped and slightly curved towards the adaxial side (Pl. VIII, 1), but as it traverses the pedicel higher up its two ends curve more and more inwards (Pl. VIII, 2), but they do not come and meet each other till the floral receptacle is reached. Thus throughout the length of the pedicel, its vascular tissue consists only of a single curved bundle and the whole organ is dorsi-ventral in construction and quite unlike an axial organ. Similar instances of dorsi-ventral symmetry in the axial parts have also been recorded by Arber (1) in several Gramineæ and a few Cruciferæ, and by Joshi and Rao (9) in *Digera arvensis*, family Amarantaceæ. All these families are wide apart in their systematic position. It is, therefore, probable that a study of the floral anatomy of more orders of the angiosperms will show this feature to be fairly widespread.

The significance of this dorsi-ventral construction of the axial organs in rare cases in the angiosperms has been discussed by Arber (1). She regards it to support the view that the stem and the leaf should not be treated as separate morphological entities. This principle is now well established from the study of the lower pteridophyta, especially the Filicales. Mrs. Arber supports it from the study of the angiosperms. There is, however, some difference in the evidence from two groups, which has not been pointed out. Among the primitive ferns like the Cœnopterideæ, it is the leaf which is stem-like in structure, and plants showing a great closeness in stem and leaf structure are to be regarded as primitive. The stem and the leaf are to be regarded in this group as primarily one morphological entity, and later on differentiation into the two organs has taken place. The situation in the angiosperms, on the other hand, is quite different. The stem and the leaf are primarily quite separate morphological units, but in some modified forms stems are reduced in their vascular construction to the condition of the leaves, and this makes a straight distinction between the two organs difficult.

Another important feature in the structure of the pedicel of *Stellera Chamaejasme* is the great development of the intercellular air-spaces (Pl. VIII, 2). Similar air-spaces are also abundant in other parts of the flower,—the gynophore (Pl. VIII, 3), the ovary wall, and the perianth-tube,—and their development to such an extent in a desert plant is notable.

(*b*) *Perianth.*—There is a well-marked constriction between the pedicel and the flower receptacle (Text-fig. 13). On the approach of the floral receptacle, the single vascular bundle of the pedicel curves more and more and ultimately its two ends meet. The stele of the thalamus thus becomes cylindrical (Text-fig. 1). From this are given off first ten perianth traces

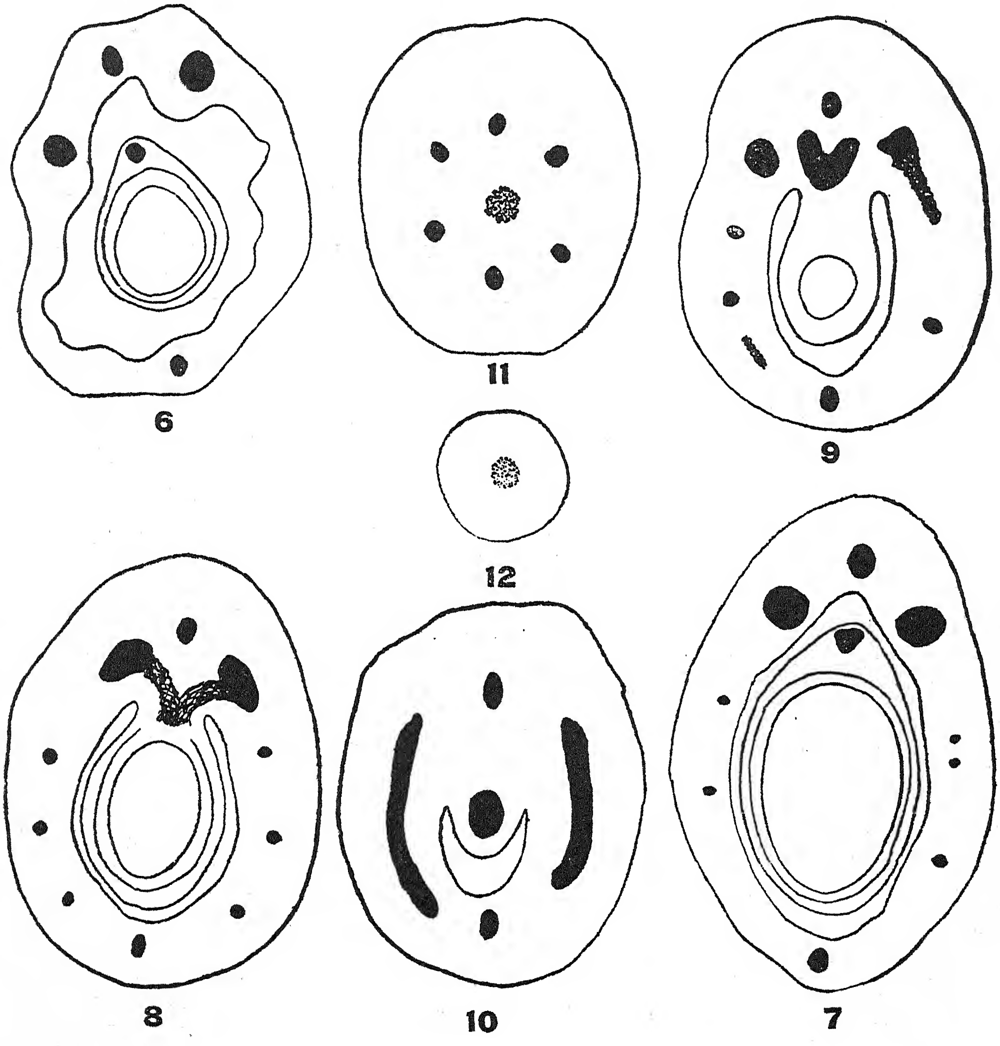
of equal bulk and at the same level (Text-figs. 2 and 3). Each trace forms a separate gap in the stele of the thalamus. After the vascular supply to the stamens has been given off, five of these alternating traces form the midrib bundles of the five perianth lobes; the remaining five fork into two, and each branch passes into an adjacent perianth-lobe. Thus every perianth lobe gets three main bundles, just as Saunders (12) has described in *Daphne Mezereum*. The perianth-tube is 10-ribbed and the 10 vascular bundles are situated to the inside of these ribs.

(*c*) *Disk-scale*.—Before the perianth-tube has detached off from the floral receptacle, or sometimes after its detachment, three of its bundles give traces to the inside (Text-figs. 4 and 5). These supply the disk-scale, which is detached off either from the receptacle itself, as in Text-fig. 13, or from the base of the perianth-tube, but in every case it receives its vascular supply from the bundles of the perianth-tube. Some of the original three bundles supplying the disk-scale may branch once. In this manner a disk-scale may show 4 or 5 bundles. The study of serial microtome sections shows that the median bundle of the disk-scale always alternates in position with the midrib bundles of the perianth-tube and the traces of the outer (upper) whorl of stamens. This shows that probably it represents a part of a much reduced corolla.

(*d*) *Androecium*.—The stamens of the upper whorl receive their vascular supply from the midrib bundles of the perianth-tube, and those of the lower whorl from the commisural bundles.

(*e*) *Gynaecium*.—After the departure of the perianth traces, there remains a complete ring of vascular tissue in the centre of the thalamus (Text-fig. 3). This ring breaks up into two small and two large bundles (Text-fig. 4). All these four enter the gynophore (Text-fig. 5), and later on the wall of the ovary (Text-fig. 6). Just at the base of the gynophore, the distance between the four bundles is nearly equal, but very soon the two larger bundles move towards one side,—towards one smaller bundle. This is the side of the ovary on which the single pendulous ovule is borne. During their further course through the ovary wall, these larger bundles go on moving more and more towards this side (Text-fig. 7), and finally near the top of the ovary come very close to each other on the two sides of one of the smaller bundles, and here give traces (Text-fig. 8), which unite on the inside of the smaller bundle and pass into the funicle of the ovule (Text-fig. 9). In the meantime, between these larger bundles supplying the ovule and the small bundle on the opposite side, three small bundles make their appearance on either side (Text-figs. 7 and 8). These are quite free from the four main bundles supplying the ovary at their lower ends but are connected with the larger bundles higher up. The larger bundles

are not completely exhausted in supplying the ovule. A good part of them remains behind. The three new small bundles now fuse with each other and with the remaining parts of the larger



Text-figs. 6-12. *Stellera Chamaejasme.* Transverse sections of the gynaecium from below upwards; Fig. 6: about the middle of the ovary; Fig. 7: a little higher up; Fig. 8: at the level of the placenta showing the origin of the vascular supply of the ovule; Fig. 9: after the departure of the same; Fig. 10: further higher up; Fig. 11: just at the base of the style; Fig. 12: transverse section of the style. Vascular tissue in all figures is shown in black. In figs. 11 and 12 the dotted part in the centre represents the conducting tissue of the style. For further explanation see text. $\times$ 135.

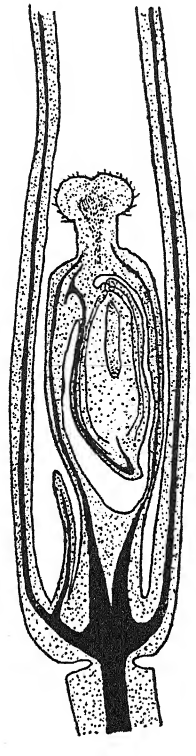
bundles (Text-fig. 11), and form one big transverse commisure of vascular tissue on either side in the ovary wall alternating in position with the two original small bundles (Text-fig. 10), which for the most part remain unbranched throughout their course in the ovary. Higher up, just at the base of the style, each transverse commissure breaks up into two bundles. This results in the formation of six bundles at the base of the style, placed in two groups of three each on either side (Text-fig. 11). The original small bundles of the gynophore form the median bundle of each of these groups. Just at this time, the transmitting tissue of the style makes its appearance in the centre. The four bundles formed from the transverse commissures merge into this tissue, while the other two simply fade away in the general tissue of the style. The central transmitting tissue alone continues through the length of the style (Text-fig. 12).

The vascular bundle of the ovule does not end in the chalaza, but goes upto the base of the nucellus (Text-fig. 13), just as Guérin (quoted in Schnarf, 13) has recorded in some other Thymelæaceæ.

The stigma is distinctly bilobed (Text-fig. 13, Pl. VIII, 4) and is not simply capitate, as has been described previously. It is provided with abundant pointed hairs, which appear to be very effective in catching pollen.

(*f*) *Interpretation of the morphology of the gynaecium.*—The gynaecium in the sub-family Thymeleae is generally described as monocarpellary, but the present study of the floral anatomy of *Stellera Chamaejasme* leads to a different conclusion. In this plant at least, it must be regarded as bicarpellary. It is in no way possible to interpret it as monocarpellary. In the angiosperms there are 1-, 3-, 5- and several-traced carpels (Eames, 4), but there is no monocarpellary gynaecium with a bilateral symmetry and 4 traces, two opposite ones of which supply the ovule, such as is the case in *Stellera*. When along with this is considered the fact that in angiosperms in general, the marginal traces of the carpel supply the ovules, the belief about the bicarpellary nature of the gynaecium of the *Stellera Chamaejasme* becomes irresistible. The distinct lobing of the stigma into two parts also supports such an interpretation and removes whatever little doubt one may have. The only question that needs discussion in this connection, and about which there can be two opinions, is the nature of the two carpels. Are the two carpels present to be regarded of the same type (monomorphic) or of two types (polymorphic)? In the greater part of the wall of the ovary before the departure of the vascular supply of the ovule, there are four bundles. Three of these lie on one side and the fourth one alone on the opposite side. The marginal bundles of the group of three supply the ovule. Thus it is quite possible to interpret this larger part of the gynaecium with three vascular

strands as one fertile carpel of the valve type of Saunders (11), and the smaller part of the gynaecium with only one small vascular bundle as a sterile solid carpel. The formation of the



Text-fig. 13: *Stellera Chamaejasme.* A longitudinal section of the lower part of the flower showing its general structure and the various vascular connections. Vascular tissue of the flower is shown in black. × 40.

six bundles, however, at the base of the style, equally disposed in two groups of three each, and the equal division of stigma into two lobes, stand against such an interpretation. On the other hand, it is quite reasonable to regard the gynaecium of *Stellera* to be composed of two carpels, each three-traced and with the marginal traces fused with those of the other, just as has been figured by Eames (4) in *Reseda odorata*. Both the carpels will then be of the same type. The small bundles in the gynophore and wall of the ovary, will represent the midrib bundles of these carpels, and the pair of larger bundles, the fused marginals of the same. The fact that these larger bundles are not equidistant from the midrib bundles of both the carpels and are more towards one side can be easily explained as due to the presence of a single

ovule on one side. On the other hand, such an interpretation is strongly supported by the ultimate formation at the top of the ovary of two bundles on either side in place of the original larger bundles and equal division of the 6 bundles then formed into two groups of three each, with the products of division of each larger bundle on the opposite sides, and the equal lobing of the stigma into two parts.

Affinities of the Family Thymelaeaceae

The family Thymelæaceæ was established at a very early date during the history of plant classification. According to Baillon (2) it was clearly indicated by Adanson in Section II of his family of Garou, and in 1789 A.L. de Jussieu gave the same group the name of the order *Thymeleae*. The affinities of this family, however, with other groups of flowering plants have never been clear. The early botanists placed it close to such families as Lauraceae, Hernandieae, and Proteaceae. This is the position assigned to it in Bentham and Hooker's 'Genera Plantarum' (3). Baillon (2) has pointed out its affinities with the Penæaceæ, Rhamnaceæ and the Celastraceæ. In 'Syllabus der Pflanzenfamilien' (5) it is placed in the order Myrtiflorae. Recently Hutchinson (6) has indicated the affinities of this family with the Nyctaginacae, and has included the two under the same order Thymelaeales.

The present investigation shows that this family is not at all comparable with the family Nyctaginaceae. Anatomy of the gynaecium of certain genera of the Nyctaginaceae like *Boerhaavia*, *Mirabilis* and *Bougainvillea* has been studied in this department (8), and it is quite different from that of the gynaecium of *Stellera*. In the Nyctaginaceae, the vascular tissue at the base of the gynaecium breaks up only into two bundles. One of these passes up as the midrib bundle of the single carpel, while the second enters the single basal ovule. The structure is nearly similar to that of *Rivina*, one of the Phytolaccaceae with a monocarpellary gynaecium (7). The similarity between the perianth of certain Thymelæaceæ like *Stellera* and the perianth of the Nyctaginaceae is to be interpreted merely as a case of parallel development. The anatomy of the flowers of other families of flowering plants mentioned above with which the affinities of the Thymelæaceæ have been pointed out by various authors from time to time is almost unknown. For this reason it is not possible here to discuss the affinities of this family with those. The only thing that can very appropriately be mentioned here is that the disk-scale in *Stellera* appears from the present investigation to be a much reduced part of the corolla. The family for this reason must have come from dichlamydeous ancestors.

Within the family Thymelæaceæ, the demonstration of a bicarpellary gynaecium in the genus *Stellera* by the present

investigation helps to bring the two sub-families, the Aquilarieæ and the Thymeleæ, further close to each other.

Summary

1. The pedicel receives a single bundle from the inflorescence axis. This forms a complete cylindrical stele only in the receptacle of the flower. Throughout the length of the pedicel there is a single curved collateral bundle and its structure is dorsiventral. The significance of such dorsiventral construction of the axial organs in the angiosperms is discussed and it is pointed out that this is to be regarded as a derived and a reduced condition.

2. The pedicel, the gynophore, the wall of the ovary, and the perianth-tube are all full of air spaces. This is notable in a desert plant.

3. The perianth-tube receives 10 traces. The disk-scale receives its vascular supply from the perianth traces, and from its relation to the perianth and staminal traces it is to be interpreted as a part of a much reduced corolla. The two whorls of stamens receive their vascular supply from the perianth traces.

4. At the base of the gynæcium there are 4 bundles, two large and two small opposite to each other. The larger bundles supply the ovule. Afterwards each of these forms two bundles, so that at the top of the ovary there are six bundles. The stigma is bilobed, and the whole gynaecium should be interpreted as bicarpellary and not monocarpellary as has been done previously.

5. The affinities of the family Thymelæaceæ with the Nyctaginaceæ as pointed out by Hutchinson are disproved, as the vascular anatomy of the gynaecium of *Stellera* is quite different from that of the gynaecium of the Nyctaginaceae.

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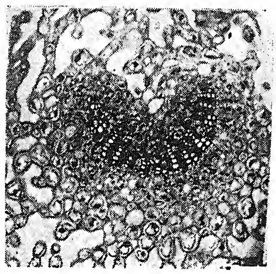
Explanation of Plate VIII

Stellera Chamaejasme.

1. Photomicrograph of central part of a transverse section of the pedicel showing the presence of a single slightly curved collateral bundle. × 90.
2. Photomicrograph of transverse section of the pedicel at slightly higher level than shown in Photo. 1; the vascular bundle is strongly curved and there is a large development of air spaces in the cortex. × 90.
3. Photomicrograph of transverse section of the gynophore showing four vascular bundles and great development of the air spaces. × 100.
4. Photomicrograph of longitudinal section of the stigma and upper part of the style showing the conducting tissue of the style, stigma covered with pointed hairs to which are attached a number of pollen grains, and the division of the stigma into two lobes. × 84.



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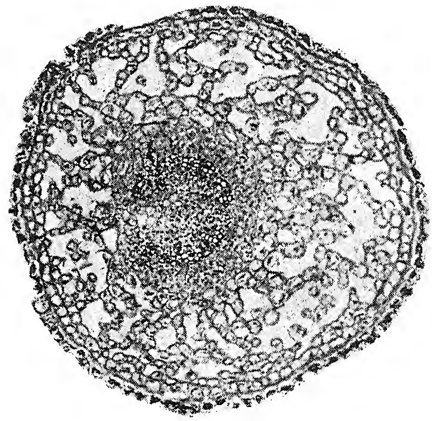

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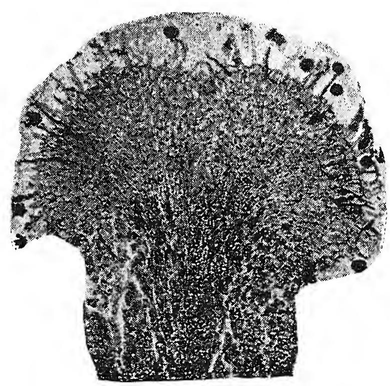

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A. C. JOSHI—*STELLERA CHAMAEJASME* LINN.

REVIEWS

CHRONICA BOTANICA, Vol. 1. edited by DR. FR. VERDOORN, Leiden, Holland, April 1935, price 15 Netherl. guilders:

DR. FR. VERDOORN is to be congratulated on this "new experiment recording the growth and the infinite scope of the Science of Plants" This welcome publication contains brief but very useful information about numerous institutions and individuals all the world over and will be a very valuable book of reference in every institution dealing with plant science.

We notice that the reference to the Indian Botanical Society is made under Coimbatore. In our opinion Societies like the Indian Botanical Society or Chemical Society should be referred to independently under separate captions like 'Botanical Society', etc. This will facilitate reference by readers who are not familiar with the location of the headquarters of the various Societies and we hope the Editors will see to this in future volumes.

As the Editor remarks, Chronica Botanica is a difficult enterprise, but it has achieved a large amount of success. We hope all concerned will co-operate to make the next volume a greater success.

P. P.

STENAR, HELGE. Embryologische und zytologische Beobachtungen uber *Majanthemum bifolium* und *Smilacina stellata*. Arkiv fur Botanik *26*A (8): 1-20. 1934.

Since Campbell's discovery (1899) of a 16-nucleate embryo-sac in *Peperomia pellucida* followed by Johnson's more detailed work on the same species in 1900, several other cases of a more or less similar nature have been brought to light in widely separated families:—Piperaceae, Gunneraceae, Euphorbiaceae, Malpighiaceae, Umbelliferae and Compositae. A feature common to all these embryo-sacs is that all the four megaspore nuclei formed after reduction division undergo two divisions so that there are 16 nuclei in the end. Very often they organise into a single egg-apparatus, two polar nuclei and 11 antipodals. Another equally common arrangement is the organization of 4 groups of 3 cells each, looking like egg-apparatuses, with 4 nuclei left free to fuse in the centre. Several other deviations besides these have also been detected.

To the families, in which the "Peperomia-type" of embryo-sac has been found, may now be added the Liliaceae. Both *Majanthemum bifolium* and *Smilacina stellata* have been investigated previously, the former having been reported to possess a

normal-type of embryo-sac (JÖNSSON 1879/80) and the latter as having one of the Lilium-type (McALLISTER, 1909). In the paper reviewed here STENAR has definitely shown that the former report is incorrect. In *Majanthemum bifolium* the megaspore-mother-cell is separated from the epidermis by one parietal layer. The 2 daughter nuclei formed after the heterotypic division are separated by a thin membrane. After the homotypic division 4 cells are formed which are irregularly arranged, but after a time all the cell-membranes formed after the hetero and homotypic divisions are dissolved and the nuclei are left free in the mother-cell. Three of these now pass to the chalazal end, while one remains at the micropylar. All of them divide resulting in an eight-nucleate embryo-sac. These 8 nuclei soon show prophasic changes and divide once again resulting in the formation of 16 nuclei—12 at the chalazal end and 4 at the micropylar. Three of the latter organise themselves into an egg-apparatus, while the fourth pairs with a nucleus from the lower group to form the fusion nucleus. The remaining 11 nuclei give rise to the antipodal cells, which are however very ephemeral.

In *Smilacina stellata* the development proceeds in almost the same way up to the 8-nucleate stage resulting in the formation of 6 nuclei at the chalazal end and 2 at the micropylar. Further development could not be traced but it appears probable that here also there is one more division resulting in a 16-nucleate embryo-sac of the same kind as has been shown to occur in *Majanthemum bifolium.*

In conclusion, the author gives a summary of the different types of embryo-sac development reported in the tribe Polygonatae of the family Liliaceae and points out the need for further investigation of other genera and species. With regard to the vexed question of the primitive or derived nature of the Peperomia-type of embryo-sac, the author adduces arguments to support the view that at least in the Polygonatae the 8-nucleate embryo-sac as exemplified by *Polygonatum* is the older one and the 16-nucleate embryo-sac as exemplified by *Majanthemum bifolium* is derived from it.

P. MAHESHWARI.

JULIANO, JOSE B. Origin of embryos in the strawberry mango. Philippine Journ. Sci. 54: 553-561. 1934.

Several papers have recently appeared on the morphology of the mango. It seems that the development of the gametophytes proceeds in essentially the same way in all the varieties, but there is a great variation in the origin of the embryos. In India, where scores of varieties of the mango are under cultivation, there is none that has been reported to be polyembryonic. JULIANO and CUEVAS (Philippine Agri., 1932)

reported that in the "pico" variety from the Philippines, there are several embryos, one of which is produced from the fertilized egg and the rest are apogamic. The first of the two authors has now investigated the strawberry mango, a polyembryonic variety imported from Hawaii into the Philippines. Here the zygote remains undivided for a long time after fertilization, its cytoplasm presents a greatly plasmolysed appearance and sooner or later completely disappears. On the other hand, the nucellar cells adjacent to the embryo-sac become filled with dense cytoplasm. Some of these, especially the ones near the micropylar end, become greatly enlarged and start dividing to form adventive embryos, but only five or less have actually been observed to develop to maturity in a seed. Since there are no egg-embryos whatever, it is concluded that the strawberry mango cannot be used as pistillate material for hybridisation, although it may serve as a polliniser.

P. Maheshwari.

RANDOLPH, L. F. A New Fixing Fluid and a Revised Schedule for the Paraffin Method in Plant Cytology. Stain Tech. 10 : 95. 1935.

After considerable trials with root tips and smears of anthers, the author recommends the following fixative designated by the abbreviation "Craf" :

Sol. A.	Chromic anhydride............	1 gm.
	Glacial acetic acid............	7cc.
	Distilled water	92 cc.
Sol. B.	Neutral formalin	30cc.
	Distilled water	70cc.

Equal parts of "A" and "B" are to be mixed before using and 12-24 hours are enough for fixation. The author recommends that the material may then be taken directly to 75 per cent. alcohol and after changing three or four times, the processes of dehydration and infiltration may be followed in the usual manner. Such a jump from an aqueous fixing fluid to strong alcohol may appear disastrous to those who customarily use a long and gradual series of alcohols, but the author claims that part of the success is actually due to "the elimination of the injurious effect of washing in water".

To save time it is recommended that butyl alcohol may be used in place of xylol. After fixation with "Craf" good staining results are obtained with crystal violet and iron-alum haematoxylin. This is evidently due to the mordanting effect of the chromic acid used in the fixative.

P. Maheshwari

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VOL. XV APRIL, 1936 No. 2

A CONTRIBUTION TO THE EMBRYOLOGY AND CYTOLOGY OF *RIVINA HUMILIS* LINN.

BY

A. C. JOSHI

Department of Botany, Benares Hindu University

Received for publication on 6th January, 1934

Contents

Introduction

The present investigation deals with microsporogenesis, megasporogenesis and development of the embryo-sac and endosperm in *Rivina humilis* Linn., a common member of the family Phytolaccaceae. The material for its study was collected from the local botanical garden. It was fixed in Allen's fluid, microtomed in the usual manner, and the sections were stained with

safranin and gentian violet. The plant is of interest as belonging to the tribe Rivinae which forms a connecting link with another family of the Centrospermales, namely, the Nyctaginaceae.

The previous contributions to the embryology and cytology of the Phytolaccaceæ may be summarised as follows. Hegelmaier (5) has described the development of the endosperm in *Phytolacca decandra*. Lewis (7) has worked out the outlines of the whole life history of the same species excluding the development of the embryo-sac. In the same plant Woodcock (15) has described the development of the seed, especially the relation of the embryo, endosperm and perisperm to one another. A few scattered references to the subject are found in the work of Rocên (9). The work up to this period has been summarised by Schürhoff (11) and Schnarf (10). Afterwards only one more paper from Mauritzon (8) has appeared describing the structure and development of the embryo-sac and embryo in *Phytolacca octandra*, *Rivina brasiliensis*, *Rivina humilis*, *Villamilla peruviana* and *Petiveria alliacea*. The chromosome number, so far as the writer is aware, has been reported only in *Phytolacca acinosa* (14),

The present investigation was started much before the publication of Mauritzon's paper, and was sent up for publication to this journal in January 1934. Due to the appearance of this work the paper has been rewritten recently.

Organogeny of the Flower

Organogeny of the flower in *Rivina humilis* takes place in the normal acropetal manner, but the development of the carpel calls for some remarks. After the rudiments of the perianth and the stamens have been differentiated, the apex of the floral axis changes into the nucellus of the single basal ovule. The wall of the carpel arises as a small protuberance on the anterior side of the flower. Gradually this protuberance becomes boat-shaped and curves over the nucellus in the form of a hood. The apex of this carpellary rudiment becomes considerably thickened at this stage as compared with the lower part and then it grows upward to form the style and downward to enclose partially the nucellus, which process is simultaneously accomplished by the growth of the margins of the rudiment around the nucellus. These finally meet on the other side of it and form a completely closed ovary.

The development of the carpel in *Phytolacca decandra* as described by Lewis (7) and in the Nyctaginaceae (Bhargava, 1) is quite similar to the above. For this reason no figures of carpel development in *Rivina* are given here. A list of other plants in which a similar development of the carpel has been recorded has been recently published by Thomas (12). Besides this a similar development of the carpel has been seen in many

Helobiae by Eber (4). From these facts it seems fairly certain that this type of development of the carpel will be found to be the general type in all uniovulate forms.

The main factors involved in this type of carpel development are the following:

1. The development of a boat-shaped carpel rudiment on one side of the ovule, the side away from the floral axis in multi-carpellary gynaecia and the anterior side in mono-carpellary gynaecia.

2. The development of the style from the apex of this carpellary rudiment, the enclosing of the ovules by the growth of its sides, and the fusion of the carpellary margins taking place from above downwards.

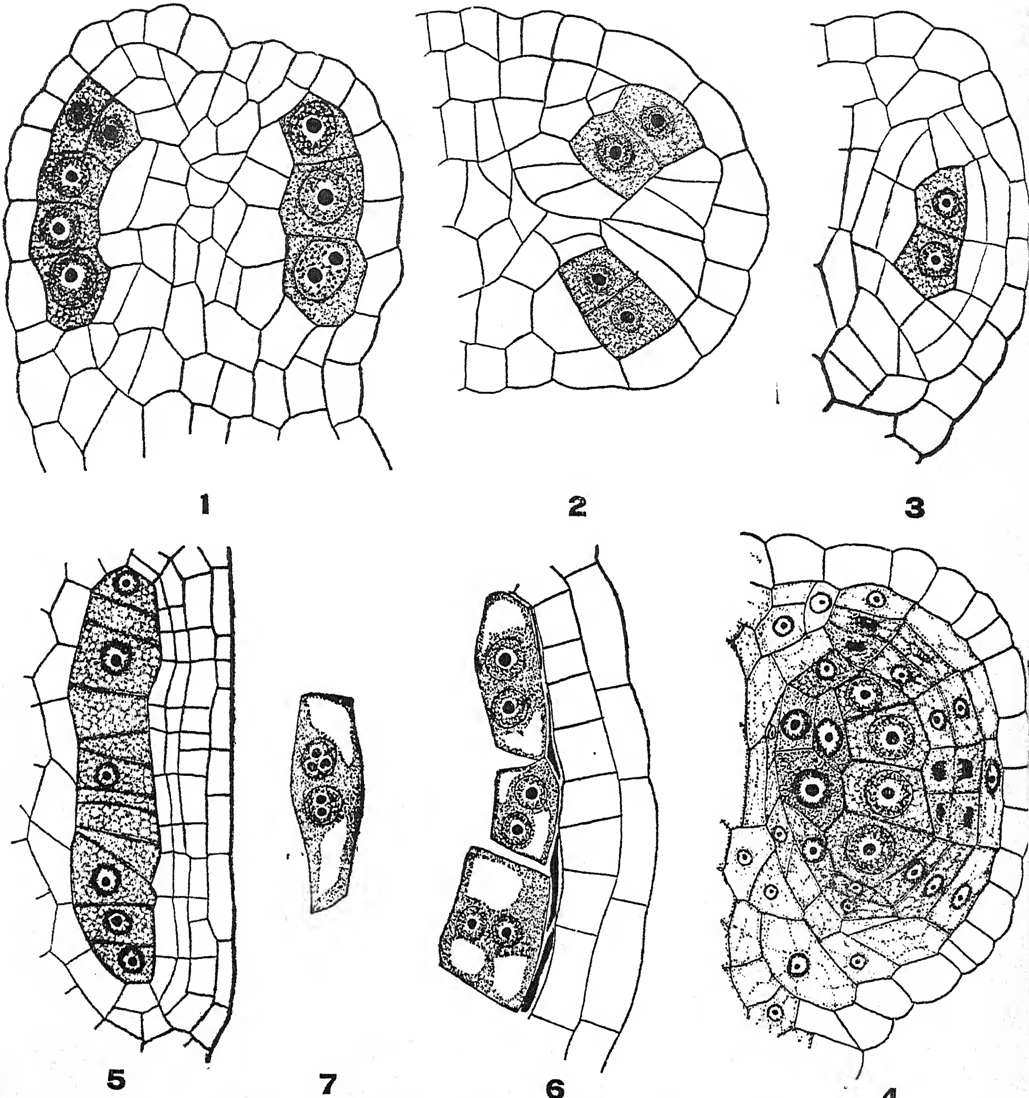
3. Dorsal growth of the carpel resulting in the enclosing of the ovule in a circinate manner.

The first and second factors from these are seen to take part in the development of all types of carpels. In carpels with terminal styles they alone are responsible for the full development of the carpel and the third factor mentioned above is absent. This condition may therefore be regarded as primitive. In carpels with lateral styles the third factor is also active simultaneously and is responsible for bringing the style and the stigma towards one side of the ovary. This condition therefore with an extra factor should be regarded as derived. The conclusions of Thomas (12) are just the reverse of these.

Microsporogenesis

The primary archesporium in each of the four lobes of the anther consists of a single row of three or four hypodermal cells (Text-fig. 1). These in the usual manner divide by periclinal walls to form the primary wall cells towards the outside and the primary sporogenous cells on the inside (Text-fig. 2). Both the primary wall cells and the primary sporogenous cells divide further by periclinal, anticlinal and transverse walls. The divisions in the wall cells, however, are more regular and even in later stages it is possible to find out the sequence of various divisions. The primary wall cells by the first periclinal division give rise to two layers (Text-fig. 3). The outer one of these does not divide any further periclinally, but the inner one undergoes another division in the same fashion. Thus the wall of each pollen-sac towards the outside of the sporogenous tissue, including the epidermis, becomes four-layered (Text-fig. 4).

The sporogenous cells by divisions in all directions give rise to a large number of spore-mother cells. A transverse section of an anther shows 4-6 of these in each anther-lobe and



Text-figs. 1—7. *Rivina humilis.* Fig. 1: L. S. of an anther showing the primary archesporium; Fig. 2. T. S. of an anther-half showing the division of the primary archesporium into primary wall and sporogenous cells; Fig. 3: T. S. of an anther-lobe showing the first periclinal division of the primary wall cells; Fig. 4: T. S. of an anther-lobe at a still later stage, showing four wall layers; the innermost of these develops into the tapetum; Fig. 5: L. S. of an anther lobe at about the same stage as Fig. 4: drawn on lower magnification; Fig. 6: part of a L. S. of the anther wall at the time of synizesis, showing binucleate tapetal cells and crushing of the wall layer to their outside; Fig. 7: a tapetal cell at the time of formation of pollen tetrads. Figs. 1-4 and 6-7: × 525; Fig. 5. × 225.

a longitudianl section 12-14 in each row (Text-fig. 5). Thus there are about 60-70 microspore-mother cells in each lobe of the anther, and the total output of pollen from each stamen of *Rivina humilis* is about 1000. In *Phytolacca decandra*, the primary archesporium in the stamens is more extensive than in *Rivina*. Lewis (7) has figured a row of about 10 hypodermal cells in each lobe of the anther. The number of microspore-mother cells in each lobe according to him is about 80. The total pollen output of single stamen, therefore, in *Phytolacca* must be in the neighbourhood of 1300. The pollen output in the family Nyctaginaceae per stamen on the average is considerably less than in the above two members of the Phytolaccaceae (Bhargava, 1).

Towards the outside of the sporogenous tissue, the tapetum is organised from the innermost wall layer; on the inside, from the adjacent eells of the connective region of the anther. These cells also divide once periclinally, when the primary wall cells undergo their first periclinal division (Text-fig. 3). They do not divide any more after this, but immediately assume the characters of the tapetal cells. Their cytoplasm becomes more dense and they begin to stain more deeply than the surrounding cells of the anther. The tapetum on the inside thus develops a bit earlier than towards the outside. Physiologically this may be related to its shorter distance from the vascular bundle in the connective. As the cells on this side receive the food earlier, it is quite natural that the tissues on this side should develope sooner than those towards the outside of the anther. It can also be argued that the pollen-mother cells have in the first instance to be fed from the connective side, and the tapetum, whose function is to feed the sporogenous tissue, differentiates earlier on this side to fulfil this function. In most of the earlier studies on the subject of tapetum differentiation, this point seems to have escaped attention, but from the nature of it, it should be the general rule in all plants.

In *Phytolacca decandra* according to Lewis (7) the tapetum is sporogenous in origin. These observations, as Mauritzon (8) remarks, are erroneous. In the Nyctaginaceae the tapetum in all instances has been found to arise from the innermost wall layer (Bhargava,1).

Tapetal cells are at first uninucleate, but very soon, by the time pollen-mother cells enter the synizesis stage, their nuclei undergo an ordinary mitotic division and they become binucleate (Text-figs. 6 and 7). These nuclei undergo no further divisions, though each of them by fragmentation of the original nucleolus, mostly becomes 2- or 3- nucleolate in later stages (Fig. 7). In the mature anthers of *Phytolacca decandra*, Lewis (13) found the tapetal cells to become 4-6 nucleate. The various nuclear divisions according to him, however, take place in an amitotic manner. In the light of recent work (Cooper, 3) this observation is probably also erroneous. The structure of the tapetal

cells in the Nyctaginaceae is mostly similar to that of *Rivina*, these being only binucleate in species of *Boerhaavia*, *Bougainvillaea*, and *Abronia* and *Oxybaphus nyctagineus*. In *Oxybaphus micranthus*, on the other hand, according to Rocén (9) the old tapetal cells are multinucleate and the same condition has been observed by Tischler (13) in the tapetal cells of the hybrid *Mirabilis Jalpa* × *M. tubiflora*. The tapetal cells in *Rivina humilis* always remain at the periphery of the pollen chamber and never push themselves in between the pollen grains, though they become free from each other laterally. The same condition has been seen by Mauritzon (8) in the species investigated by him. In most of the Nyctaginaceae, the condition is quite similar that of *Rivina*, but in *Bougainvillaea glabra* and *Mirabilis*, Rocén (9) and Tischler (13) respectively have observed the tapetal cells pushing themselves in between the pollen grains and forming a false periplasmodium.

As the tapetum develops in *Rivina*, the layer of wall cells just outside it is crushed by its growth (Text-fig. 6). The wall layer just beneath the epidermis develops into the fibrous endothecium with spirally thickened cells. On maturity, therefore, when the tapetum has disorganised, the wall of the anther consists only of two layers, the epidermis and the endothecium. A disorganisation of the third layer, in a way similar to that of *Rivina*, has also been observed in the Nyctaginaceæ by Rocén (9), though this is not a feature common to the whole of that family. In *Boerhaavia* species, for instance, all the wall layers remain in tact upto the last (1).

The pollen-mother cells in the resting condition are polyhedral. Their wall is very thin and remains unthickened. They are distinguished from the other cells by the usual features, namely, the large nuclei and the dense and deeply-staining cytoplasm. The nuclei are about 10μ in diameter and their size increases to 12μ or so in latter stages. They possess in most instances one, rarely two nucleoli (Plate IX, Fig. 2), and even in the resting condition show a distinct reticulum formed from deeply staining chromatin bodies (chromocentres) and fine connecting threads (Plate IX, Fig. 1). In the nucleoli one or two nucleolini are visible throughout the prophase stages of the first meiotic division.

With the onset of the first meiotic division, the nucleus enlarges and the reticulum becomes more distinct (Plate IX, Fig. 2). The deep staining material from the chromocentres begins to flow out along the linen network, and ultimately from the breaking down of this (Plate IX, Figs. 3 and 4) it resolves into the usual zygotene stage (Plate IX, Fig. 5). The nucleolus takes no part in the development of this zygotene thread. Its size remains undiminished and it shows no notable connection with the latter. The whole of the chromatin seems to come directly from the

chromocentres visible in the resting condition of the nucleus. No distinct parallel arrangement of the threads is visible at this stage.

The chromatin thread now begins to recede from the nuclear wall and to condense and so passes into the synizesis stage (Plate IX, Figs. 6—9). The condensation is fairly strong to obscure the identity of the thread (Fig. 9). The nucleolus during this stage remains invariably outside the contracted thread. In one instance two contraction knots were seen inside a nucleus at this stage (Fig. 8).

The early stages in the development of the open spireme from the synizesis stage and the unsegmented open spireme with uniformly distributed chromatin were not observed in the material studied. There is no second contraction. The segmented pachytene threads (Plate IX, Figs. 10—12) are frequently found to show a parallel arrangement. This is especially clear from Figs. 11 and 12. The mode of chromosome pairing therefore is parasynaptic. The condition is very similar to that described in *Bougainvillaea glabra* by Cooper (2).

By a dissolution of the lightly staining portions of the segmented threads, the nucleus enters the diakinesis stage (Plate I, Figs. 13 and 14). The nucleolus even at this stage is as prominent as in the beginning. The bivalent chromosomes are all of a uniform shape. They are short deeply staining bodies, slightly longer than broad. The individual members of these bivalents do not show any split at this stage. Consequently, there is no formation of tetrads such as has been described by Cooper (4) in *Bougainvillaea* species. The total number of bivalents in a nucleus of a microsporocyte of *Rivina humilis* has been counted to be 54 (Plate IX, Figs. 14 and 17). The diploid number of chromosomes in this species is therefore 108 and the haploid number 54. In *Phytolacca acinosa* according to Tischler (14) the haploid number of chromosomes has been found to be 18 by Morinaga, Fukushima, Kano, Maruyama and Yamasaki. The chromosome numbers thus in the family Phytolaccaceae as far as these are known show a close correspondence with those found in the families Chenopodiaceae and Amarantaceae (Joshi, 6).

While the nucleus is still in early diakinesis, it appears to be drawn out at certain points and assumes an irregularly stellate form (Plate IX, Fig. 12). Spindle fibres later on appear from these points and extend from one end of the nucleus to the other. An entirely intranuclear multipolar achromatic figure thus develops even before the dissolution of the nuclear wall (Plate IX, Fig. 15). The nucleolus is still present at this stage. As the nuclear wall dissolves, the nucleolus suddenly disappears and the achromatic figure becomes bipolar (Plate IX, Fig. 16). It is quite well marked from the general cytoplasm, possesses sharp acute poles and is formed of straight fibrils. The anaphase presents no

remarkable feature. During telophase, the achromatic figure becomes barrel-shaped (Plate X, Fig. 1) and the fibrils composing it are seen to become thicker, loose, and wavy. The chromosomes are found grouped in arcs at each pole of the spindle. No split is noticed in the chromosomes either during anaphase or telophase.

After the chromosomes have become grouped at the poles of the spindle, a few vacuoles appear on the inside of each group (Plate X, Figs. 2 and 3). These gradually increase in size (Fig. 4) and ultimately meet and form one large vacuole (Fig. 5). The chromosomes get distributed in this vacuole, become connected by fine threads, a nuclear wall is formed around the vacuole and the nucleolus makes its appearance. In this manner the two daughter nuclei are organised (Figs. 6 and 7). The chromosomes inside these remain distinct, though they become somewhat diffuse.*

The homœotypic division proceeds in the usual manner. The two spindles are found to be arranged mostly at right angles to each other (Plate X, Fig. 8), and the four grand-daughter nuclei are formed inside the pollen-mother cells arranged in a tetrahedral manner (Figs. 9 and 10). In rare instances only are the spindles during the homœotypic metaphase found to be parallel and a bilateral arrangement in a pollen tetrad is seen (Fig. 11).

The process of cytokinesis is seen to take place by furrowing (Plate X, Fig. 9) in the same manner as in *Phytolacca decandra* (Lewis, 13) and *Bougainvillaea glabra* (Cooper, 2).

The young pollen grains, while they are still within the mother cell, begin to show a few small vacuoles close to the nucleus, but otherwise they are completely full of granular cytoplasm (Plate X, Fig. 10). As soon as, however, the mother cell wall dissolves and they begin to increase in size, they become very prominently vacuolated all round (Fig. 11). The cytoplasm is found to be mostly restricted to the vicinity of the nucleus, a small amount is found lining the external wall and the rest is in the form of thin strands connecting the former two. During later growth of the pollen, these vacuoles are gradually filled up, the process beginning from the centre and extending towards the periphery (Figs. 12 and 13). The exine and the intine are differentiated in the normal manner.

As the pollen grains reach the size of about 25μ, their nucleus divides and gives rise to a large tube nucleus and a small generative nucleus (Plate X, Fig. 14). No organisation of a generative cell has been seen at this stage, though from what is known in the allied families its possibility cannot be ruled out. The tube nucleus is at first quite spherical, but in the mature

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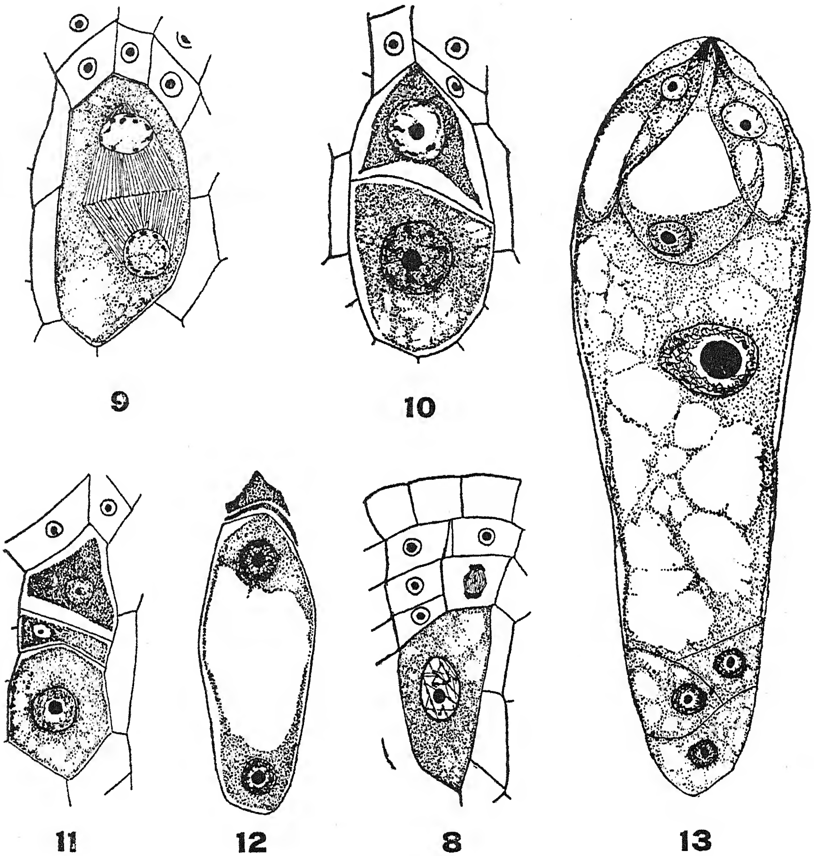
* It is hoped to publish a more detailed account of the telophase later on.

pollen it becomes elongated and more or less crescent-shaped. The generative nucleus again divides and a small amount of cytoplasm gets aggregated round each of its daughter nuclei. In this manner it gives rise to two somewhat elongated male cells (Plate X, Fig. 15). In *Phytolacca decandra*, according to Lewis (13) and in most of the Nyctaginaceae, the pollen is shed at the two-nucleate stage. The three-nucleate condition, however, has been observed in *Oxybaphus micranthus* by (Rocèn 9). Thus there are no fundamental differences between the families Phytolaccaceæ and the Nyctaginaceæ in this respect.



Text-figs. 8—13: *Rivina humilis*; a few stages in the development of the female gametophyte. Fig. 8: a part of the nucellus showing a megaspore-mother cell and two to three layers of parietal tissue as yet all formed from the primary wall cell; Fig 9: first division of the megaspore-mother cell, telophase; Fig. 10: the dyad; Fig. 11: three uni-nucleate megaspores; Fig. 12: two-nucleate embryosac with two degenerating megaspores at the apex; Fig. 13: the mature embryosac showing three antipodals, a large secondary nucleus, an egg cell and two synergids with long pointed apices. × 525.

The mature pollen grains of *Rivina humilis* are about 40μ in diameter. Their exine is quite smooth and is perforated by a few simple pores.

Megasporogenesis, Embryo-sac and Endosperm

The writer's observations on the structure and form of the ovule, nucellus, primary archesporium, megasporogenesis, development and structure of the embryosac and development of the endosperm agree exactly with those of Mauritzon (8)—see summary—except in two points. According to him "the megaspore-mother cell normally divides into two dyad cells. Both of these divide further, but in the dyad cell no cell wall between the nuclei is developed. The tetrad thus consists of three cells of which the upper is two-nucleate". The writer has not seen in his material in any case nuclear division taking place in the upper dyad cell. Thus here all the three megaspores are uninucleate (Text-figs. 8—12). As regards the synergids, Mauritzon says that he has not observed any beaks in *Rivina*, though these were seen by him in the other genera. In the writer's preparations (Text-fig. 13) this structure is seen in *Rivina humilis* also.

The development of the endosperm begins before the development of the embryo. There is no division of the oospore even at the 6-nucleate condition of the endosperm, but after this the growth of the embryo speeds up. When there are about 25 nuclei in the endosperm, the embryo is about 10-celled.

Summary

1. The various flower parts develop in normal acropetal succession. The carpel at first develops from one side of the nucellus of the single basal ovule. It becomes boat-shaped and curves over the apex of the nucellus and from this condition the ovule is enclosed both by the growth of the margins and the apex of this carpel rudiment. The development is exactly similar to that of the carpel in the Nyctaginaceae and some other plants. The main factors taking part in this type of carpel development are analysed and it is shown that it should be regarded as a derived condition.

2. The primary archesporium in each of the four lobes of the anther consists of a row of 3 or 4 hypodermal cells. The primary wall cells give rise to three layers, the outer of which develops into the fibrous endothecium, the middle dissolves and the innermost develops into the tapetum. The tapetal cells are binucleate with each nucleus in the later stages usually 2-3 nucleolate. The pollen output per anther is about 1000.

3. During the two meiotic divisions, nucleolus is not seen to take any part in chromosome formation. The pairing of the chromosomes takes place parasynaptically. The achromatic figure is entirely intranuclear and is seen to develop even before the disappearance of the nuclear wall. At first it is multipolar, but as the nuclear wall dissolves, it becomes bipolar. During inter-kinesis, the nucleolus makes its appearance in the daughter nuclei. The method of formation of these nuclei is described. After the homoeotypic division, the grand-daughter nuclei are found to be arranged mostly in a tetrahederal manner, only rarely bilaterally. Cytokinesis takes place by furrowing. The haploid number of chromosomes is 54 and the diploid number 108.

4. The mature pollen grains show one tube-nucleus and two male cells. Their exine is quite smooth and is perforated by a few simple pores.

5. The ovule is campylotropous with a well-developed nucellus and two integuments. There is usually a single hypodermal primary archesporial cell, which divides periclinally to form a primary wall cell and the megaspore-mother cell. The epidermal cells at the apex of the nucellus and the primary wall cell by dividing in all planes give rise to a large amount of parietal tissue, about 12-14-layered by the time the 8-nucleate embryo-sac is organised. The megaspore-mother cell gives rise only to three megaspores, the upper cell of the dyad not undergoing the second division. The lowermost of these is the functional one and develops into the embryo-sac in the normal manner.

6. The mature embryo-sac is 8-nucleate. The egg-cell is larger than the synergids. The latter have elongated and pointed apices. The three antipodals have nothing remarkable about them. The polar nuclei fuse with each other at an early stage.

7. The endosperm nucleus divides before the oospore.

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Explanation of Plates

Plate IX.

Fig. 1. Microspore-mother cell with nucleus in the resting condition. × 2100.

Figs. 2-5. The nucleus in various early prophase stages. Fig. 2 shows two nucleoli wihin the same nucleus. × 2100.

Figs. 6-9. Synizesis. × 2100.

Figs. 10-13. The nucleus in various stages from the segmented spireme to the diakinesis. Figs. 11 and 12 show the parasynaptic pairing of the chromosomes. × 2100.

Fig. 14. The nucleus at the diakinesis stage. The figure has been re-constructed from a number of serial sections to show the total number of 54 bivalents. × 3000.

Fig. 15. Late diakinesis, showing the origin of the achromatic figure. × 2100.

Fig. 16. Metaphase. × 2100.

Fig. 17. Metaphase cut crosswise showing the haploid number of chromosomes. × 3000.

PLATE X.

Fig. 1. Microspore-mother cell with the nucleus in early telophase. × 2100.

Figs. 2-5. One side of the spindle during telophase, showing the formation of nuclei from chromosomes. × 2100.

Fig. 6. Pollen-mother cell in late telophase with fully formed daughter nuclei. × 2100.

Fig. 7. Polar-view of a nucleus during interkinesis. × 2100.

Fig. 8. The second meiotic division; metaphase. × 2100.

Fig. 9. Pollen-mother cell showing the tetrahederal arrangement of the four grand-daughter nuclei and cytokinesis by furrowing. × 2100.

Fig. 10. Young pollen grains still inside the mother cell wall arranged tetrahedrally. × 1050.

Fig. 11. Young pollen grains after the dissolution of the mother cell wall arranged bilaterally. They show large vacuoles all round. × 1050.

Figs. 12-15. Various stages in the development of pollen. The vacuoles are gradually filled from the inside outwards (Figs. 12 and 13). The nucleus divides into the large tube nucleus and a small generative nucleus (Fig. 14). The latter gives rise to two male cells (Fig. 15). × 1050.

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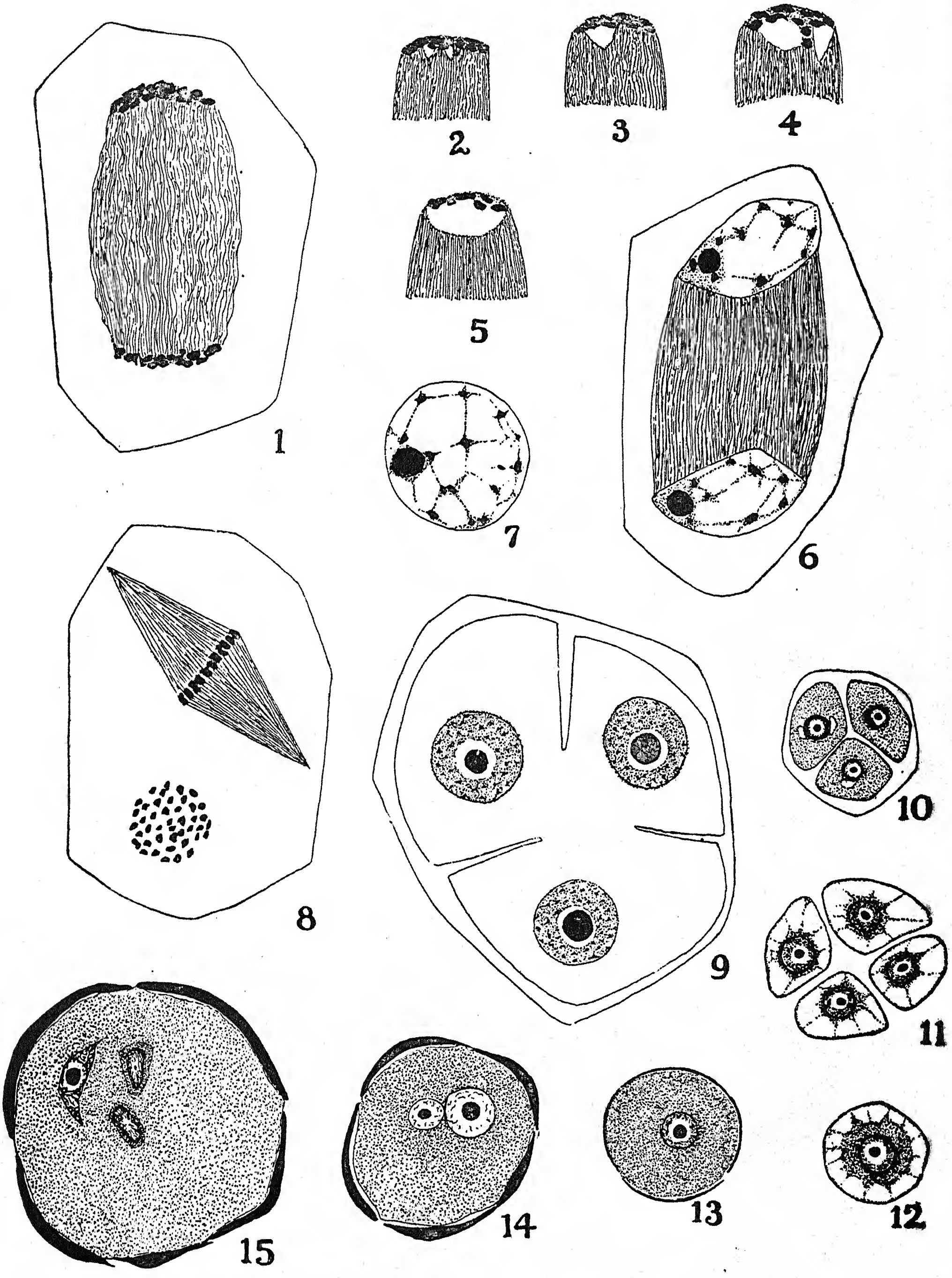

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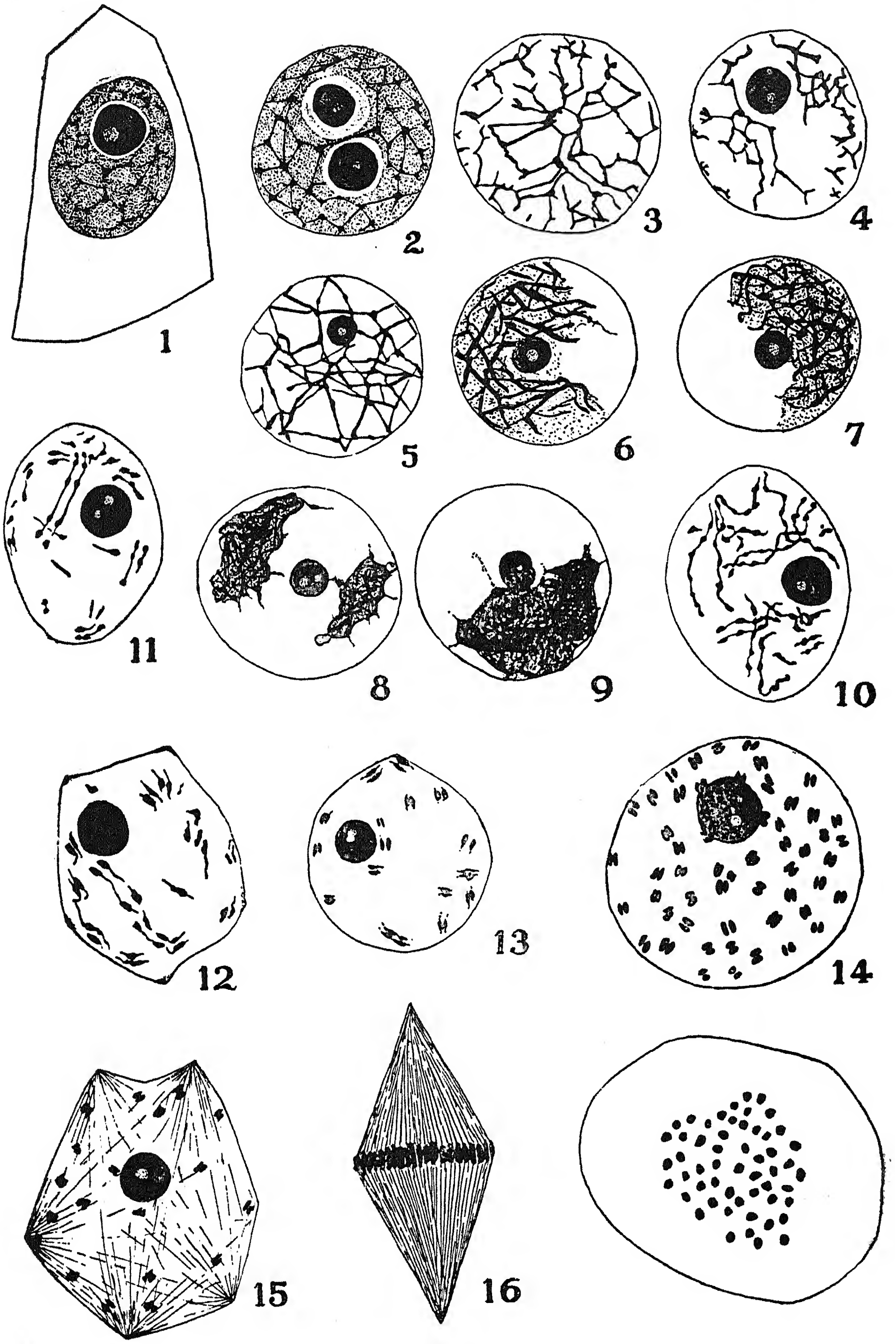


A. C. JOSHI—*RIVINA HUMILIS* LINN.

A CONTRIBUTION TO THE MORPHOLOGY OF *ANTIGONON LEPTOPUS* HOOK. & ARN. *

BY

V. S. RAO

Received for publication in March, 1934

Introduction

Antigonon leptopus is a favourite garden climber. It occurs in two varieties — the white-flowered and the pink-flowered. Both these continue to flower and seed profusely during practically the whole year. It is the occurrence of the plant in two varieties differing only in the colour of the flower that attracted attention, and it was suggested by Prof. N. K. Tiwary that it will be interesting to study the two varieties.

On referring to Schürhoff (7) and Schnarf (6) it was found that the life history of this plant is not at all worked out. A cytological study of the Polygonaceae is made by Jaretzky (5) but that upon *Antigonon leptopus* is extremely fragmentary. As regards this plant, he only says that the chromosomes are small in size, and that their number in the equatorial plates is very variable, ranging between 37 and 40, but never exceeding 40. He also mentions that 40 is probably the correct number. The lower numbers are ascribed by him to defective counting. That is all that he mentions for *Antigonon leptopus*.

The development of the flower of this plant has been studied by Bauer (2), but the life history is completely unknown.

The present paper deals with a study of the pink-flowered variety only.

Material and Methods

Floral stages of this variety were fixed on bright sunny days at about 1 p.m., in Allen's modification of Bouin's fluid, and in Carnoy's fluid. To hasten the penetration of the fixing fluid, an exhaust pump was used. The further procedure was the same as usual for the paraffin method. Sections were cut 6-8 microns thick. Staining was done in (1) Iron-alum haematoxylin, (2) Iron-alum haematoxylin, using safranin as a counterstain, and (3) a combination of safranin and gentian violet.

* This work has been partly aided financially by Prof. N. K. Tiwary.

The fixing was equally good with both the fixatives used. Slides stained in the first two combinations were better than with the third.

Megasporogenesis

The archesporium is hypodermal in origin, and is not strictly confined to a single cell (Figs. 1 and 2). It may even consist of as many as five cells. All these archesporial cells do not necessarily occur in the form of a connected plate, but ordinary nucellar cells may intervene between them (Fig. 1). The archesporial cells generally cut off parietal cells by periclinal walls (Figs. 2 and 3) although eventually only one — the one in the median line of the nucellus — pursues its further development. Similar accessory archesporial cells have been found by Dudgeon (3) in *Rumex crispus* to the extent of as many as seven. In *Rheum*, Edman (4) found, almost always, 2 to 3 primary archesporial cells. Schnarf (6) mentions similar conditions in *Fagopyrum sagittum* and *Oxyria digyna.*

The primary parietal (Fig. 3) divides further by both anticlinal and periclinal walls to form usually about five or six cells (Figs. 4 and 5).

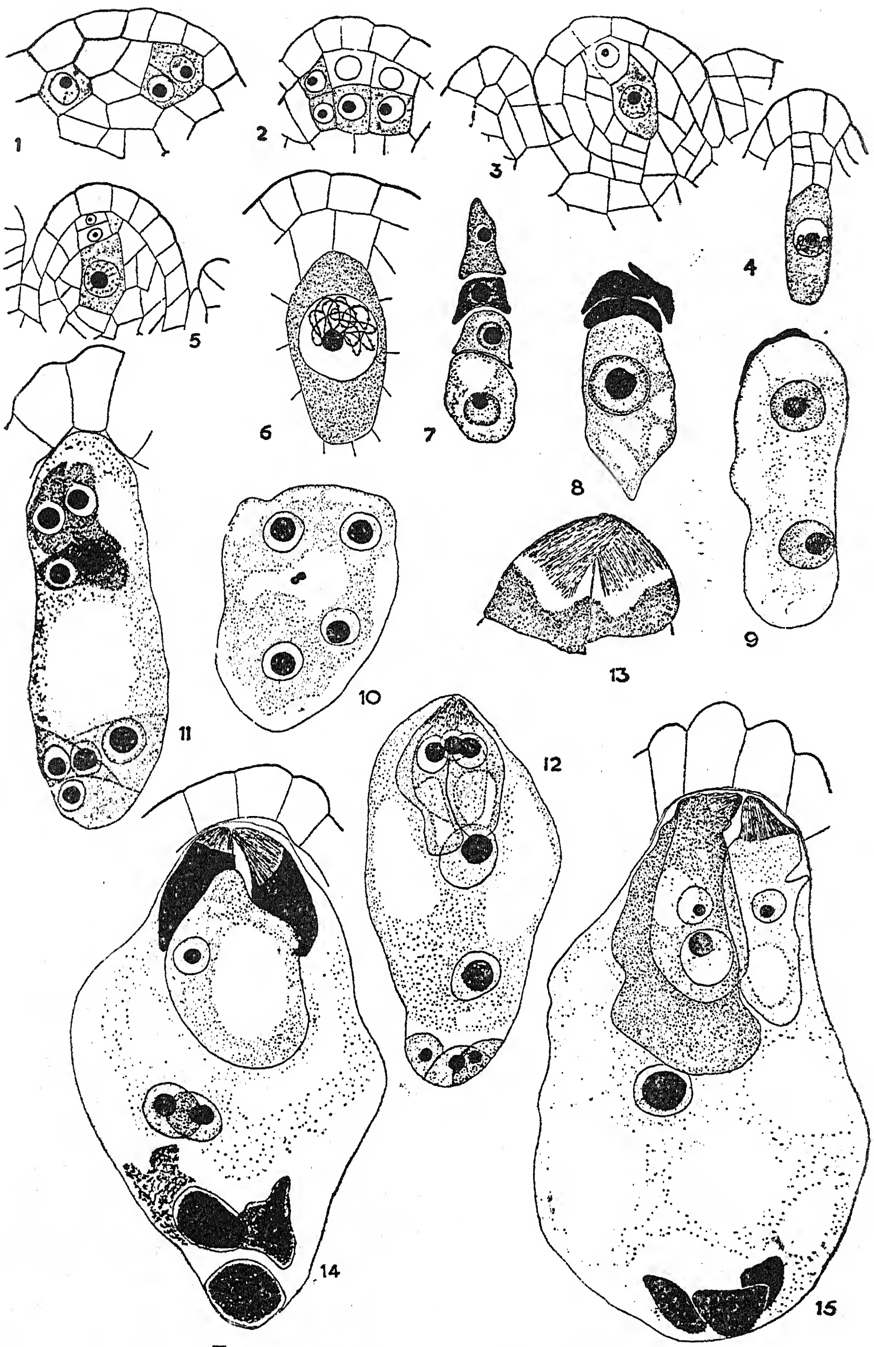
The sporogenous cell, when it is situated about three cells deep in the nucellus (Fig. 4), enlarges in size, becoming the megaspore mother cell. In one or two cases, this enlargement of the cell has taken place even when there is only a single parietal cell (Fig. 6). This megaspore mother-cell divides by two successive divisions to form a linear tetrad (Fig. 7). In *Rumex crispus*, Dudgeon (3) reports a T-shaped tetrad, and such a condition, according to the statement made by Edman (4), seems to be characteristic generally of the Rumescineae. In *Antigonon leptopus*, such a tetrad was never met with, and, evidently, a linear tetrad is the rule here.

The size of the spores of the linear tetrad shows a tendency to reduction from base upwards (Fig. 7), and it is the innermost megaspore that becomes the functional embryo-sac, while the other three spores degenerate (Fig. 8).

Development of the Embryo-sac

The functional megaspore gradually enlarges and develops into the embryo-sac. Its nucleus divides and the two daughter nuclei pass as usual to the two poles (Fig. 9). By two more successive divisions, a normal 8-nucleate embryo-sac is formed (Fig. 11). At this stage, the sac is thrice as long as it is broad, and on the micropylar side it comes to lie directly beneath the epidermis, due to the dissolution of the overlying cells (Fig. 11). Such a hypodermal position of the embryo-sac has been reported also for *Rumex crispus* by Dudgeon (3). Woodcock (9) notes

embryo-sac with the degenerating megaspores. ×480. Fig. 9. 2-nucleate embryo-sac. ×480. Fig. 10. 4-nucleate embryo-sac. ×480. Fig. 11. Young 8-nucleate embryo-sac. ×400. Fig. 12. Young embryo-sac. ×400. Fig. 13. A piece of the synergids, showing the filiform apparatus. ×545. Fig. 14. Embryo-sac just before the fusion of the polar nuclei. ×400. Fig. 15. Embryo-sac after the fusion of the polar nuclei.



Text figures 1 to 15. *Antigonon leptopus*

Fig. 1. Nucellus showing hypodermal archesporial cells. ×320. Fig. 2. Nucellus, the archesporial cells of which have cut off parietal cells. ×365. Fig. 3. Nucellus showing a single sporogenous cell and a parietal cell. ×320 Fig. 4. The megaspore mother cell. ×400. Fig. 5. Showing the development of the parietal tissue. ×320. Fig. 6. Megaspore mother cell, only one-cell deep beneath the epidermis. ×400. Fig. 7. Tetrad of megaspores. ×400. Fig. 8. Uninucleate

that in certain Polygonaceae, the epidermis of the nucellus becomes a nutritive jacket which is of importance for the nutrition of the developing endosperm. No such indication is to be found in *Antigonon leptopus.* The nutritive function of the nucellar epidermis is not supported by the published investigations on the other plants of the family. It is very doubtful whether it plays any such role although the embryo-sac comes to be directly beneath it by the absorption of the parietal tissue.

The embryo-sac is 8-nucleate and normal as the figures indicate except for the following slight variations. During later development the two polar nuclei become definitely bigger than the others including even the egg nucleus. The synergids enlarge in size more rapidly than the egg cell, and each develops a filiform apparatus (Figs. 13-15). Among the Polygonaceae the occurrence of such a filiform apparatus has been recorded by Strasburger (8) for *Polygonum divaricatum.* The ends of the synergids bearing the filiform apparatus tend to bend towards each other (Fig. 13). After fertilization the synergids degenerate (Fig. 14).

As development proceeds the egg-cell becomes far larger than the synergids (Figs. 14 and 15).

The antipodal cells are always uni-nucleate and at about the time of fertilization they undergo degeneration (Figs. 14 and 15).

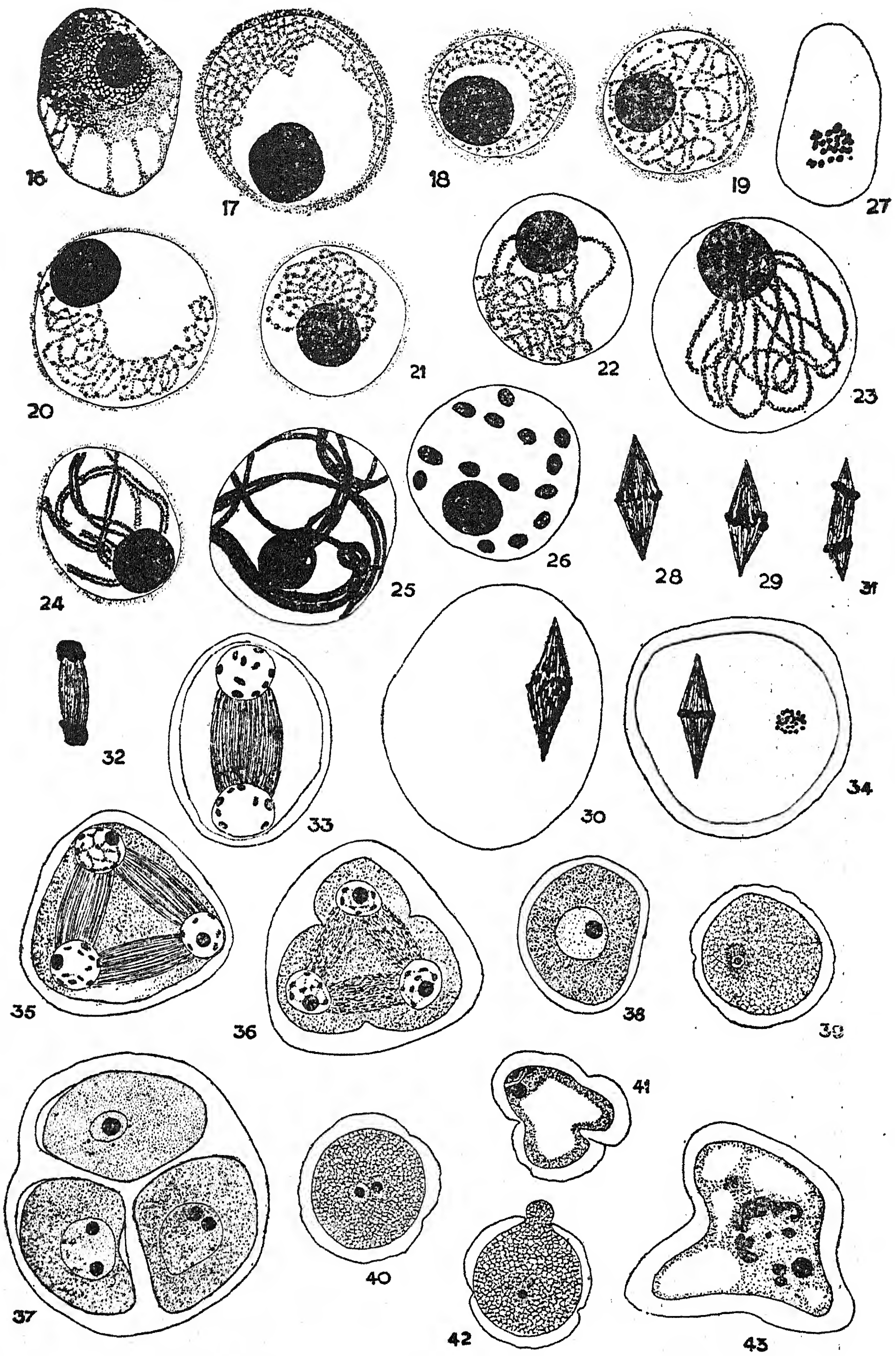
The two polar nuclei come to the centre of the embryo-sac and lie side by side (Figs. 12 and 14), fusing at the time of, or even just after, fertilization. This is contrary to the statement made by Dudgeon (3) and others that the polar nuclei fuse early. Later, the secondary nucleus migrates so that it lies in close contact with the egg (Fig. 15). Stages of the further phases of the life history are not obtained.

Meiosis in the Pollen Mother Cell

The pollen mother cell in the resting stage (Fig. 16) has a slightly vacuolated cytoplasm. The nucleus is spherical, with a prominent nuclear membrane, and a big nucleolus which occupies nearly half of the nuclear cavity. In young pollen mother cells, the whole of the space between the nucleolus and the nuclear membrane is occupied by fine chromatic reticulum (Fig. 16), but in older nuclei, the reticulum is seen always to occupy a position adjoining the nuclear membrane (Fig. 17), leaving a clear space round the nucleolus. The large nucleolus seldom lies in the centre of the nucleus. In the young condition, the reticulum is uniform without any knotty protuberances.

At the approach of the heterotypic prophase, the reticular threads begin to thicken and develop upon them, small knots (Fig. 18). Simultaneously with this thickening, small portions of the reticulum disappear, resulting in a continuous threadwork

Fig. 29. Beginning of anaphase. ×545. Fig. 30. Anaphase. ×545. Fig. 31. Advanced anaphase. ×545. Fig. 32. Beginning of telophase. ×545. Fig. 33. Telophase. ×545. Fig. 34. Homoetypic division. ×545. Fig. 35, Organization of the tetrad nuclei. ×545. Fig. 36. Tetrad formation by furrowing. ×545. Fig. 37. Mature tetrad. ×545. Fig. 38. Young uninucleate microspore. ×215. Fig. 39. Advanced microspore. ×215. Fig. 40. Two-nucleate pollen grain. ×215. Fig. 41. Pollen grain with the generative cell. ×215. Fig. 42. Intine extruding through a germ pore. ×215. Fig. 43. Degenerating pollen grain. ×215.



Text figures 16 to 43. *Antigonon leptopus.*

Fig. 16. Pollen mother cell in the resting condition. ×910. Fig. 17. Nucleus of pollen mother-cell—Beginning of prophase. ×1,140. Fig. 18. Prophase. ×1,140. Fig. 19. Continuous chromatic thread formed. ×1,140. Fig. 20. Pre-synizetic stage. ×1,140. Fig. 21. Synizetic knot. ×1,140. Fig. 22. Synizetic knot formed away from the nucleolus. ×1,140. Fig. 23. Loosening up of the synizetic knot. ×1,140. Fig. 24. Open spireme, with double chromatic thread. ×1,140. Fig. 25. Pre-diakinesis. ×1,140. Fig. 26. Diakinesis. ×1,140. Fig. 27. Chro-

(Fig. 19). At this stage, the spireme extends throughout the nuclear cavity. Gradual thickening and contractione of the spireme takes place, and this results in bringing out the knotty appearance more prominently. The contraction of the spireme takes place towards the nucleolus and along the nuclear membrane (Fig. 20). When the spireme gradually shrinks along the nuclear membrane, it is thrown into numerous coils (Fig. 20). This results ultimately in the spireme forming a loose knot round the nucleolus and this, as contraction proceeds, becomes tight (Fig. 21). This is the synizetic knot, and in some cases, it may not lie wholly in contact with the nucleolus (Fig. 22); the main mass of the knot may be slightly away from the nucleolus, but the latter is connected with the synizetic knot by a few chromatc threads. The stage of the synizetic knot seems to last for a considerable length of time, and it is made up of a densely convoluted thread. At this stage it is not possible to say whether it is single or double.

The knot gradually loosens up (Fig. 23) and the chromatic thread appears much thicker than before, and in the act of this loosening up, it is thrown into a number of loops diverging from the nucleolus (Fig. 23). The knotty appearance of the presynizetic stages is lost in the open spireme stage (Fig. 24) and the doubleness becomes apparent.

In spite of very careful examination, no second contraction is to be found here, so that it can fairly be concluded that it is absent. In *Carica Papaya* also, Asana and Sutaria (1) failed to observe the typical second contraction.

The thread gradually thickens, and the loops widen out, and it is at this pre-diakinesis stage that a thick double thread is clearly visible (Fig. 25). This double chromatic thread gradually contracts and then gets broken up transversely (Fig. 26) into the bivalent chromosomes. These latter (Fig. 26) are in the form of globular bodies, and are not rod-shaped or twisted or of any other shape. Such globular bivalents have been recorded in *Carica Papaya* by Asana and Sutaria (1). It is after the bivalent chromosomes are formed that the nucleolus is disorganised. Since their formation, the bivalent chromosomes lie distributed irregularly within the nuclear cavity. It is very rarely that the nucleus occupies a central position in the nucular cavity, mostly being eccentric in position. Immediately after the double thread of chromatin has segmented into the constituent bivalents, these latter seem to be connected by some slender achromatic material, but this is soon dissolved away.

The nuclear membrane breaks down quickly, and the bivalents arrange themselves at the equatorial region (Fig. 27). Since the origin of the globular bivalents, the doubleness is invisible.

In two cells which were cut transversely along the equatorial plate, 24 chromosomes were observed (Fig. 27), and observations

of chromosomes in the divisions of the nucellar cells showed the diploid number to be about twice this. Jaretzky (5) counted the diploid number as 40. He found lower numbers also sometimes, which he explains as due to wrong counting, but never more than 40. My observations are evidently in opposition to his, as the diploid number here comes to be 48. I confirm Jaretzky's statement that the chromosomes are small.

A bipolar spindle makes its appearance (Fig. 28) some of the fibres of which attach themselves to the chromosomes. The achromatic figure has got straight sides and pointed ends (Fig. 28). Due to the usual eccentric position of the nucleus of the pollen mother cell, the spindle also, in most cases, lies to one side (Fig. 28). No stages were obtained which showed the origin of the achromatic figure.

The chromosomes are drawn unequally towards the poles (Figs. 29 and 30). During these stages, granules of varying size and unknown origin are sometimes found in the surrounding cytoplasm (Fig. 30).

Although the chromosomes are drawn unequally at first from the equatorial plate, when they are about half-way from the poles (Fig. 31) all of them again come so close to one another that the individual chromosomes are not distinguishable, and they reach the poles simultaneously, where they form a darkly staining mass (Fig. 32).

Stages showing the details of telophasic changes are not obtained. The individual chromosomes again separate widely from one another, and a nuclear membrane appears enclosing them (Fig. 33). The chromosomes, within the nuclear membrane, appear as small, rod-shaped or spherical bodies. The achromatic figure at this stage loses the straightness of its sides, and becomes barrel-shaped with curved sides (Fig. 33).

In the interkinesis, the chromosomes do not form a reticulum but remain separate. A nucleolus is found to have developed in some and not developed in other interphasic nuclei. It seems that nucleoli are developed, but the homeotypic division follows very soon, in preparation to which they are dissolved away. The interphase is of short duration.

The nuclear membrane of the daughter nuclei is dissolved away, and the chromosomes arrange themselves at the equatorial region (Fig. 34), entering upon the metaphase of the homeotypic division. The division of the two nuclei is simultaneous, and the spindles are at right angles to each other (Fig. 34), so that the future arrangement of the four microspores is tetrahedral. The spindle resembles that of the reduction division, and has straight sides when young, and is barrel-shaped at the telophase (Figs. 43 and 35).

It has been difficult to find the anaphasic stages of this division, as it passes very rapidly. The early telophasic changes are essentially similar to those of the reduction division. After the nuclear membrane is formed in the young condition, the chromosomes are individually distinguishable (Fig. 35). Later, fine fibres are found to connect them (Fig. 36). A nucleolus makes its appearance, and the chromatin within the nuclear cavity is gradually organised into a reticulum. Only three spores are in focus at a time (Fig. 37). The nucleus of each microspore contains one and occasionally two nucleoli.

While the four nuclei of the tetrad are being organized, the cytoplasm begins to constrict between them, and these constrictions go deeper (Fig. 36), dividing the tetrad by furrows (Fig. 37).

Development of the Pollen Grain

After the tetrad formation, the young microspores round up and become free. The nucleus is large (Fig. 38) and contains one, rarely two small nucleoli. In the usual way the wall gets differentiated into the thin and delicate intine, and the thick exine. The microspore enlarges considerably (Fig. 39), and its nucleus divides into two—a tube nucleus and a generative nucleus (Fig. 40). The latter may either be smaller than the tube nucleus or it may be equal to it in size (Figs. 40, 42). It organizes a small, usually lens-shaped, cell (Fig. 41) by the side of the spore wall. Each pollen grain has three germ pores, through one or more of which, the intine bulges out forming short bulb-like extrusions (Fig. 42). Such extrusions have been recorded by Dudgeon (3) for *Rumex crispus*. He also finds long pollen tubes protruding out from the germ pores within the stamens, but such a condition is not observed here.

The pollen grain is shed in the two-celled stage.

Degenerations

Degenerations seem to be very common in the anthers from the synizetic stage of the pollen mother cell onwards. Sometimes the contents of all the anthers of a flower are found to be degenerating. Although degenerations are common from the synizetic stage onwards, they occur most abundantly in the pollen grains. Pollen grains which are going to disintegrate lose their spherical shape and become irregular (Fig. 43). They get crushed up at the weak points — namely the germ pores. The nucleus of the pollen grain breaks up into a number of fragments (Fig. 43) giving sometimes a false appearance of amitosis. In *Rumex crispus*, according to Dudgeon (3), degenerations occur even to a larger extent. Whereas he finds widespread degenerations in the ovary also, they are absent in *Antigonon leptopus*.

The cause of the degenerations is not known.

Summary

(1) The number of the primary archesporial cells is variable, ranging from 1 to 5, although only one pursues its further development.

(2) The megaspore mother-cell produces a linear tetrad of spores, the innermost one of which functions as the embryo-sac.

(3) A normal 8-nucleate embryo-sac is developed.

(4) A filiform apparatus caps each synergid.

(5) The polar nuclei are larger than even the egg nucleus.

(6) The diploid chromosome number is 48, and the chromosomes are small.

(7) The mature pollen grain contains a tube nucleus and a generative nucleus.

(8) Widespread degenrations occur in the pollen grains. These have not been observed in the ovary.

Here I take the opportunity of thanking Prof. N. K. Tiwary for his kind and able guidance throughout the course of the investigation, and also for kindly going through the manuscript. I also thank Dr. Y. Bharadwaja for permitting me to work in the laboratory, and for giving me all the facilities for research.

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PHYSIOLOGY OF ZONATION

Effect of Light and Temperature on Zonation in *Acrothecium lunatum* Wakker.

BY

B. S. NIGAM, B.SC. (AGRIC.)

Plant Pathological Section, Agricultural College, Cawnpore

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Contents

I. Introduction

The formation of concentric rings or zonation in artificial cultures of certain fungi is a very common phenomenon, which has been the subject of particular study by a number of mycologists. It was observed by Hall and Stevens (6) in *Ascochyta crysanthemi* Stevens and he and others held that zones in their cultures were not due to light or temperature relations as they did not

coincide with the fluctuations of these two factors. Bisby (1) said that zones might be induced by alternate changes in the temperature in constant darkness. Chaudhuri (3) observed this phenomenon in *Colletotrichum biologicum* at low temperatures. Hedgecock (7) found it in cultures of *Cephalothecium, Penicillium* and *Mucor,* when they were exposed to day-light or blue-light, but the zones were not produced in continued darkness or in red or orange lights during day. Brown (2) has observed in various strains of *Fusarium fructigenum* that the nature of zonation changes with the nature of the medium. Zones in the cultures of *Cercospora dolichi* E and E were considered by Coons and Larmer (4) to be due to the differential rate of linear growth of the submerged mycelium. The same fungus has recently been studied by Singh (11) and he claims that alternating light and darkness play the most important part in their formation and that other factors such as fluctuating temperature and dilution of media are of less importance. Hall (5) has very recently studied the effect of light and darkness on the cultures of *Sclerotinia fructigena.* He has attempted to study the effect of continuous light. He concludes that alternation of light and darkness is essential for the production of zones. Moreau (10) has also tried to note the effect of continuous light or darkness on *Penicillium glaucum.* He concluded that alternating light and darkness are not the chief factors which caused zonation. Mitra (9) described the light-history of *Acrothecium penniseti* but he did not mention anything about the formation of zones in its cultures. He only stated without ascribing any reasons that the colour of the growth changed from grey to pink.

Thus there are various views expressed so far regarding the production of zones in artificial cultures. Some hold that alternation of daylight and darkness is the causal factor, while others say that the fluctuating temperature is responsible for this phenomenon. This investigation was taken up with a view to find out the extent of responsibility of the two factors of light and temperature in the production of zones. With this in view the fungus *Acrothecium lunatum* Wakker. was first cultivated on different media and then on the most suitable one at various temperatures in daylight, continuous electric and red lights and absolute darkness.

II. Method of Study

The fungus was isolated under the usual asceptic conditions from red spots on the sorghum leaves on two per cent. rice-agar medium. On this medium the fungus did not spore. So in order to obtain sporing cultures the fungus was transferred to the autoclaved sorghum leaves from the rice-agar medium cultures. The growth on the autoclaved leaves was smoky in colour and the cultures spored vigorously. The spores measured from 18 to 25 μ in length and 9 to 11 μ in breadth, and were borne acrogenously in groups of two to five at the tips of the conidiophores. The latter arose as side branches from the submerged mycelium.

A loopful of thick suspension of spores or a bit of mycelial growth was placed in the centre of a petri-dish, 9 cm. in diameter, containing about 10 cc. of the medium. Everytime a set of six petri dishes was prepared, two of which served as the control. They were placed upside down on the table in the laboratory. For observing the effect of red light the cultures were kept upside down inside a wooden box, all the sides and the top of which were of double sheets of thick ruby glass.

Cultures could not be kept at the constant temperatures inside the incubator so as to avoid the introduction of the other factor of the absence of light inside the incubator, which on account of being painted black on all sides makes the inside of it absolutely dark. So the average of the outside

maximum and minimum temperature was taken. For studying the effect of temperature a range of 20°F, between 73°F and 93°F, was thought sufficient, because beyond 93°F the cultures dry up in a short time. The variation of temperature in the closed space was not more than 2-3°F and hence only the average of the daily fluctuation was taken and recorded.

The effect of incubation, where the temperature was constant and the light factor was rigorously excluded, was also studied.

III. A—The Effect of Day-light

(i) *At the average temperature of 73° F.*—Cultures of the fungus were prepared on two per cent. sugar-agar, sorghum-leaf-extract-agar, two per cent rice-agar as well as on potato-juice-agar media (9). These different media were used with a view to find out a most suitable one for the production of pigmented zones. The cultures were kept near a window in the laboratory, where the average temperature was 73°F.

All the cultures produced colonies, which were uniformly white for the first twenty-four hours. After this period the older region of the colonies became pink, while the peripheral region remained white. This white portion corresponded with the darkness of the previous night. During the early hours of the morning and a few hours after sunset when the light was mild, the shade of the growth remained white and as the day advanced the growth turned pink. The latter was again followed by a white ring corresponding with the night. This alternation of white and pink rings continued till the whole of the dish was covered.

The hyphae in the pink areas were profusely branched and filled with pinkish granules and large oildrops. In the white areas they were sparsely branched.

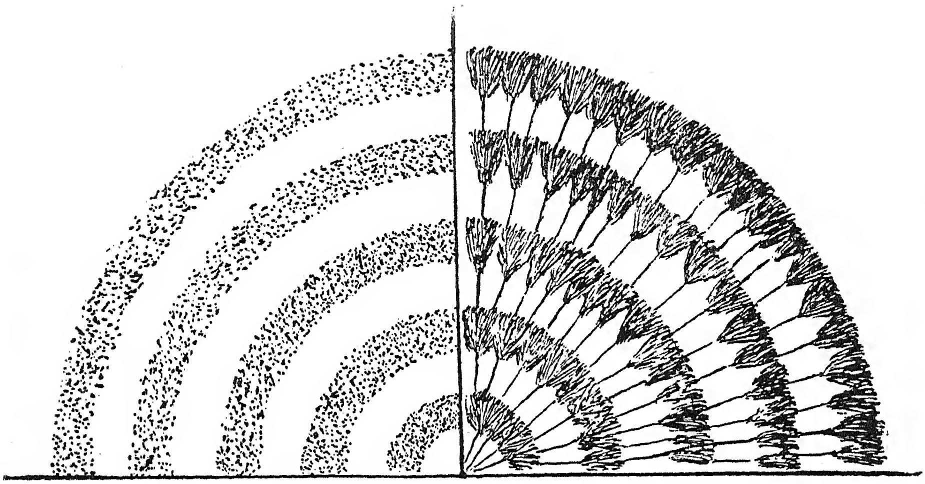
Of all these media rice-agar was found to be the most suitable one for the production of zones. The pink zones were deeper in shade and more distinct than on other media. In all the subsequent studies rice-agar was therefore used.

The nature of zonation is diagramatically represented in Text-figure I.

(ii) *Average temperature of 76°F*—Rice-agar medium cultures gave a white colony during the twenty-four hours and the subsequent growth produced the usual alternate pink and white zonation just in the same manner as at 73°F.

(iii) *Average temperature of 90°F.*—Rice-agar medium cultures produced the alternate pink and white zones of growth.

(iv) *Average temperature of 93°F.*—Rice-agar medium cultures produced the usual alternate pink and white zonation even at the high temperature of 93°F.



Diagramatic representation of zones in *Acrthoecium lunatum.*
Left—As visible to the naket eye.
Right—As visible under the low power of the microscope.

B—Effect of Continuous Electric Light

Since during night it is complete darkness so the cultures were exposed to continuous electric light all the twenty-four hours inside a dark room with a view to obtain a continuous exposure to light.

(i) *Average temperature of 76° F.*—Rice-agar medium cultures were exposed to continuous electric light. The growth was white upto 72 hours but it turned smoky afterwards. A ring of white growth appeared on the periphery of the smoky colony. This white growth with the advance in age also turned smoky. There was always a white ring of young growth surrounding the old smoky colony. The radial growth was very rapid. The mycelium was throughout a submerged one. The cultures did not spore. Though he could not satisfactorily test the effect of continuous light on *Fusarium fructigenum,* Hall (5) found clear indications that the exposure to light causes a sporiferous type of growth in contrast to the sterile type obtained in darkness. After five days' continuous exposure the cultures were transferred to daylight in the laboratory. The subsequent growth showed the usual alternate pink and white zonation, without in any way affecting the

previous growth. The control dishes produced the typical alternate pink and white zonation from the very beginning without any interruption.

(ii) *Average temperature of 93° F.*—Rice-agar medium cultures gave exactly the same results as at 76°F, the only difference being that there were a few aerial hyphae in the cultures, which were quite absent at 76°F.

C—Effect of Red-Light

(i) *Average temperature of 73° F.*—Rice-agar medium cultures were kept in the filter-box, which was kept near the laboratory window. They received only red rays during the day and none in the night. Another set of cultures was kept outside in the daylight as control. The cultures that were kept inside the filter-box showed the alternate pink and white zones of growth like the outside ones, but in the former the pink zones were deeper in shade and more prominently marked out than the latter. Distinct, though slight, increase in pigmentation has been observed by Johnson (8) in *Fusarium batatis,* which was exposed to full range of visible light for a week or more right from the time of inoculation.

(ii) *Average temperature of 76°F.*—An electric bulb was kept lighted in front of the filter-box all the twenty-four hours with a view to expose the cultures to continuous red light. Rice-agar medium cultures produced a white colony during the first twenty-four hours but during the next twenty-four hours a deep pink ring was seen in the colony, which was concentrically surrounded by a white ring of young growth. Hall (5) has also observed in *Fusarium fructigenum* that the pink zone is not visible until the second day after initiation. On the third day the dishes were again examined and it was observed that the old growth had all turned deep pink, which was surrounded by a white ring of the previous few hours. On the next day it was found on examination that the white ring, which was seen the previous day, had also turned deep pink, but the young growth of the last few hours was visible as a white ring around the uniformly pink colony. This was observed unaltered till the dishes were fully covered.

(iii) *Average temperature of 93°F.*—Rice-agar medium cultures were kept similarly inside the filter-box at an average temperature of 93°F. The colony was smoky in shade, leaving a white ring of young growth on the periphery. This white ring later on changed to smoky shade. This process was observed uninterrupted till the dishes were full.

IV. Effect of Absolute Darkness

A—*General.*—Cultures were kept inside bigger Petri-dishes, which were coated black all over and kept in dark room. They were also wrapped in black paper.

(i) *Average temperature of 76°F.*—Rice-agar medium cultures were kept in the dark at the average temperature of 76°F. The colony was at first white, which after forty-eight hours showed a smoky growth surrounded on the outside by a white ring. The mycelium was submerged and the cultures were not sporing. On transfer to daylight the alternate pink and white zones reappeared in the subsequent growth.

(ii) *Average temperature of 93°F.*—Rice-agar medium cultures similarly kept, produced a smoky colony surrounded by a white ring of young growth, which with the advance in age also turned smoky. The colony appeared uniformly smoky with the ring of white growth on the periphery. The mycelium was mostly submerged but there was a fairly good proportion of aerial hyphae. On transfer to daylight the subsequent growth showed alternate pink and white zonation.

B—*Effect of Incubation at 63°F.*—Inside the incubator two conditions are provided; *viz.*, a constant temperature and absolute darkness. Cultures on rice-agar medium produced a colony, the old growth of which was uniformly aerial and very dense. No zones could be seen. The shade of the colony was bottle-green. All the cultures were vigorously sporing. Even the young growth was bottle-green, though not aerial. Sub-cultures from this growth produced the typical alternate pink and white zonation when kept outside in daylight.

C—*Incubation at 93°F and at the average temperature of 76°F alternately.*—Cultures on rice-agar medium were incubated at 93°F. The growth was of a dense bottle-green shade as described above. After two days' incubation they were brought out in daylight at an average temperature of 76°F. The subsequent growth showed alternate pink and white zonation, without in any way affecting the previous growth. After two days the cultures were retransferred to the incubator, where the typical dense bottle-green growth appeared without in any way affecting the alternate pink and white zones produced in the daylight. Transfer from one condition to the other was done two or three times and the growth typical to each condition was obtained without in any way affecting the old growth.

VI. Discussion

Two zones of growth are produced in the laboratory conditions every twenty-four hours; one pink and the other white. This exactly corresponds with the alternation of day and night. Pink zones had the profusely branched mycelium, while the white ones had so in a lesser degree. Hall and Stevens have suggested that there is some sort of periodicity in the mycelial branching which causes zones. There could be two possible causes for zonation in

the above cultures; *viz.*, temperature and light. The temperature, which is low at night and high during the day, may possibly be the causal factor for the periodic mycelial branching and consequent zonation. Another explanation for these pigmented zones is that during night the cultures are not exposed to any rays of light and hence the growth is white and that during the day time all the rays act upon the cultures and cause pigmentation.

Pink and white zones of growth are produced at all temperatures between 73°F and 93°F in daylight. This leads one to the assumption that light is responsible for the production of pigmented zones particularly when no such zones are produced in dark and they reappear on exposure of the same cultures to daylight at the same temperature, which consequently seems to have little effect. This confirms the observations made by Singh (11) on *Cercospora dolichi* E and E.

The absence of pink zones inside the incubator can be accounted for in two ways. One is the absence of light since the inside of it is coated black and the other is the high temperature of incubation. The latter induces aerial growth. Since the temperature inside the incubator is constant the growth is uniformly aerial; so no zones are visible in them.

Red rays deepen and make prominent the pink zones, when cultures are kept inside the filter-box, admitting only red rays during the daytime only. This suggests that red rays of light perhaps have some effect on the production of pink pigmentation. If the cultures are exposed to red rays continuously, a perfectly pink colony is produced at 76°F and a smoky one at 93°F. This corroborates the suggestion of Chaudhuri that red rays of light are effective in producing pink pigmentation at low temperatures only.

Since the peripheral region of the last few hours' growth is white, which, with the advance in age, becomes pink, it becomes quite evident that red light is effective in producing pink pigmentation only about twelve hours after their radiation.

No alternate pink and white zones are produced on exposure to continuous electric light, while exposure to solar light and pure red rays at the same temperature produce alternate pink and white zones and uniformly pink colony respectively.

VII. Summary

Two zones of growth are produced every twenty-four hours in the cultures of *Acrothecium lunatum* Wakker. when exposed to daylight during day and darkness in the night. The zones are white and pink alternately, which exactly coincides with the alternation of night and day.

Alternate pink and white zones of growth are produced at ali temperatures between 73°F and 93°F in daylight.

No zones of growth are produced in absolute darkness. The growth inside the incubator is also devoid of zones but is aerial and of dense bottle-green shade.

Smoky colony surrounded by a white ring of young growth is produced in continuous electrict light at the temperatures of 76°F and 93°F.

Deep pink colony surrounded by a white ring of young growth is produced in continuous red light at 76°F, while a smoky one surrounded by a white ring is produced at 93°F in the same light.

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TWO NOTES ON SOUTH INDIAN STRIGAS

BY

EDWARD BARNES

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1. THE NUMBER OF RIBS ON THE CALYX IN THE SOUTH INDIAN STRIGAS

Both in the Flora of British India and in the Flora of the Presidency of Madras, the number of ribs on the calyx is made the chief key distinction for the Genus *Striga*. In the latter flora, Gamble gives the following analysis:—

Calyx 5-ribbed, the ribs running to the apex of each lobe

1. *orobanchoides*
2. *densiflora*

Calyx 10-ribbed, occasionally 15-ribbed but the secondary ribs always ending at the sinus between the lobes.

3. *lutea*

Calyx 15-ribbed, all ribs continued to the apex of the lobe

4. *euphrasioides*
5. *Masuria*

Like other parasitic plants, strigas usually become black on drying, and it is difficult to make out the details of pressed specimens. An analysis based on herbarium specimens is therefore likely to be only approximate. In the flowering stage, the calyx is narrow and the ribs are close together and not always easily distinguishable, and after the capsule has opened the calyx becomes dry and brittle and is often incomplete. The calyx is, therefore, best examined some days after flowering when the capsule is enlarging and the calyx is somewhat distended. On examining numerous living plants, it was found that the following analysis expresses the facts more correctly than that given by Gamble:—

Calyx 4-ribbed, one rib running to the apex of each of the four normal lobes, the fifth lobe reduced to a scale and having no rib

1. *orobanchoides*

Calyx 5-ribbed, one rib running to the apex of each lobe

2. *densiflora*

Calyx having 9 to 17 ribs, usually 11 to 13,—one running to the apex of each of the 5 lobes and 6 to 8 ending at the sinuses between the lobes

3. *lutea*

Calyx 16-ribbed, 3 ribs running to near the apex of each lobe, and one ending at the sinus between the front 2 lobes

4. *euphrasioides*

It appears to be doubtful whether *S. Masuria* should be regarded as a South Indian species. All records of it except one are from North India. The only South Indian record is from Guindy near Madras, where it has not been found in recent years, and no authentic specimen of this plant is available in South Indian herbaria.

Below are given some details of these calyces.

Striga orobanchoides Benth.

The calyx in this species (Tambaram specimens) appears to the naked eye to be four-lobed, each lobe having one rounded rib running to its tip. The cross-section of the calyx is approximately square, the four ribs being at the corners, and the square being concave at the sides and slightly convex front and back. The whole calyx is deep red and fleshy. The lobes are short, triangular and acute, and have pointed white hairs on and near their margins. On removing the calyx from the plant and examining it with a lens, a small roundish scale with a few white hairs is usually found at the back sinus. This is best seen from the side when the capsule is ripening, as it stands out from the back surface. It is sometimes practically absent, and only rarely is it developed sufficiently to have the trace of a rib. When the capsule is ripe, the calyx has become brown and membranous, and the four ribs are reduced to four black lines; in one specimen there was a black line at the front sinus but in no specimen was a black line seen at the back sinus representing the degenerated fifth rib. The hairs are usually larger in proportion than is suggested by the drawing (Fig. 1.)

Striga densiflora Benth.

The calyx in this species has 5 ribs, one running to the tip of each lobe. As in most strigas, the back lobe is smaller than the other four, but it has a well-marked rib running along its whole length. The lobes are ovate, acute and flexed outwards, and their margins are fringed with stiff pointed hairs having somewhat bulbous bases.

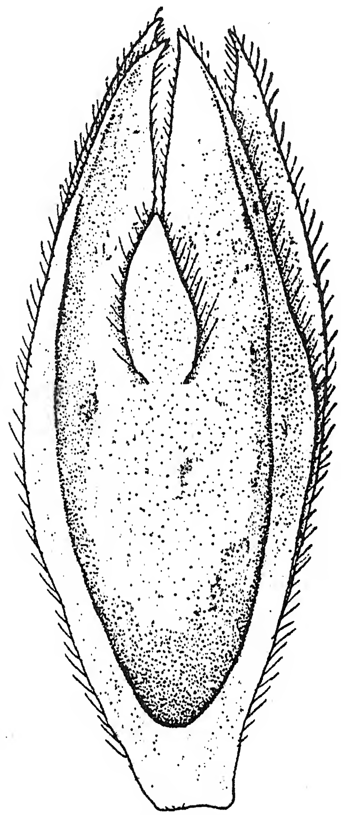


Fig. 1. Back view of detached calyx of *Striga orobanchoides* Benth. showing the reduced fifth lobe. × 15.

Striga lutea Lour.

This is a rather variable species. The form of this plant found at Tambaram has a small cream-coloured corolla. As a result of the examination of numerous calyces, it is concluded that the number and arrangement of the calyx ribs is as follows. There are always 5 main ribs, one running to the tip of each lobe, except in abnormal calyces having six lobes. There are usually two secondary ribs ending at the front sinus, sometimes three, but only rarely less than two. At each of the side sinuses there is one secondary rib; rarely one of these secondary ribs is absent but more than one rib was not found in any case. Normally there are two ribs at each of the back sinuses but there may be three or, less frequently, only one. The most usual arrangement of secondary ribs is therefore

$$\begin{array}{ccccc} & & \bullet & & \\ & 2 & & 2 & \\ 1 & & & & 1 \\ & & 2 & & \end{array}$$

The form of this species found on the Nilgiris has a sulphur-yellow corolla. In specimens of this form collected on Gudalurmalai (c. 6,000 ft.) there were, as with the other form, usually 2 secondary ribs at the front sinus and one at each of the side sinuses (in about 20 per cent. there were 3 ribs at the front sinus and occasionally 4, but in 98 cases out of 100 examined there was one rib at each of the side sinuses). In this form there was usually only one rib at each of the back sinuses and much less frequently two. In this form also the number of calyx lobes was more frequently increased (9 out of 100 had 6 lobes and one 8 lobes). In specimens of this yellow-flowered form collected at Ponmudi, Travancore (3,500 ft.), there were two ribs at the front sinus in about half the cases and more than 2 in the rest. There were two ribs at each back sinus about as frequently as one. One rib at each side sinus was the most constant feature. One calyx had 12

secondary ribs arranged
●
2 2
2 2
4

In this species the ribs are square in cross-section and roughly hairy. Two narrow ribs close together are often difficult to distinguish from a single broad rib. Not infrequently a rib is divided into two for part of its length. In the diagram of *S. lutea* in Fyson's Flora of South Indian Hill Stations, Vol. II, page 371, only the 5 main ribs are shown.

Striga euphrasioides Benth.

There are two forms of this plant found in the Chingleput District. The small form grows in grassy places and dries blackish. The large form grows in rice fields and is parasitic on rice; it dries grey-green.

In the small form there are almost always 16 ribs on the calyx. Three ribs run to near the tip of each of the five lobes, and one secondary rib ends at the front sinus (Plate XI) or joins one of the ribs next to it a little above the sinus. In the few cases where the secondary rib is absent there is usually a space for it formed by the arching away from each other of the lower halves of the neighbouring main ribs. In a few cases there is a secondary rib at one of the other sinuses. When the two valves of the capsule open, they press the side lobes of the calyx outwards and partially separate them from the other lobes. The two front lobes, however, almost always remain erect and attached to each other, the secondary rib between them probably strengthening their attachment. The ribs are rounded and the part of the calyx between them is membranous and translucent and often of a purple tint.

The large form of this species is more variable than the small form. Normally it also has three ribs to each lobe and one secondary rib at the front sinus. There are, however, not infre-

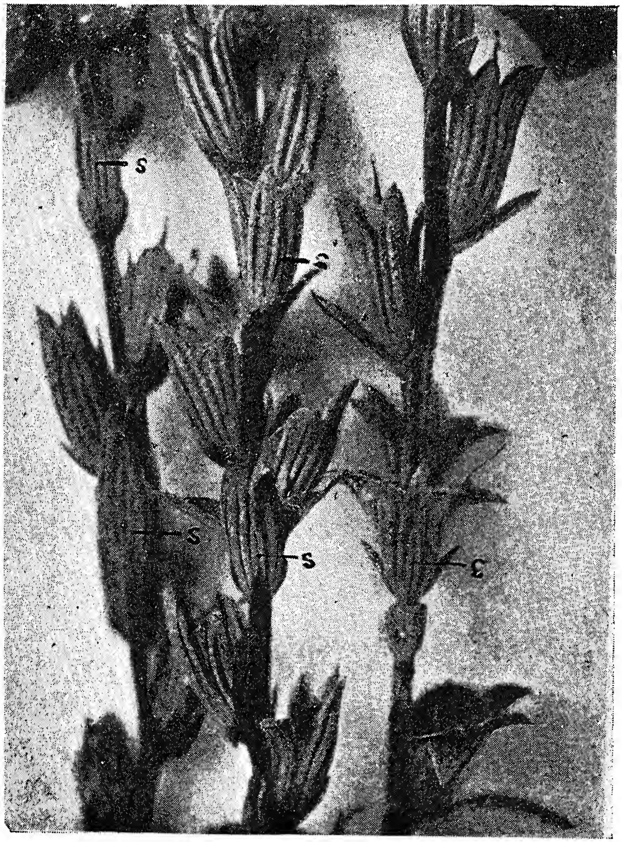
quently secondary ribs at one or more of the other sinuses. Wight's diagram (Wt. Ic. t. 855) does not show the number of ribs on the calyx.

2. *STRIGA DENSIFLORA* BENTH., A PARASITE

According to Gamble (Flora of Madras, p. 967), *Striga densiflora* Benth. is "not recorded as parastic". It may therefore be of interest to record a case of parasitism in this species. In the neighbourhood of Tambaram there is a large area of short grass that during the rainy season bears a strikingly abundant crop of a white-flowered striga, which on examination proves to be *S. densiflora,* Benth. A number of tufts of this grass with striga plants growing in them were dug up with large clumps of earth. The earth was carefully washed away in running water and the roots of the striga were traced down. In most cases the roots were found to end in swellings attached to the roots of the grass. These swellings are obviously suckers. A number of such specimens were pressed and dried, and after drying the parasitism was very clearly seen as the striga roots had become black and so could be readily followed amongst the light-coloured grass roots. The striga was identified by the following characters — a green plant with white corolla, calyx with 5 ribs, bracts longer than the calyx, spikes of flowers often very long (up to 7 ins. in plants, only 8 ins. tall). The identification was confirmed by Kew from a formalin specimen. The grass was kindly determined by Mr. C. E. C. Fischer as *Iseilema Wightii* Andrews.

Explanation of Plate XI

Striga euphrasioides Benth. Photograph showing the secondary rib at the front sinus. ×2.



E. BARNES—*STRIGA EUPHRASIOIDES* BENTH.

A SILICIFIED DICOTYLEDONOUS WOOD:

Dryoxylon mohgaoense sp. nov. from the Deccan Intertrappean Beds of India

BY

K. P. RODE, M.SC.

Department of Geology, Benares Hindu University

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Introduction

Few plant-bearing localities are known in India which have yielded a sufficiently varied and rich angiospermous fossil flora of the Upper Cretaceous or Eocene Age. The rock formations of this period in India include, beside others, the extensive igneous lava flows known as the Deccan Traps covering large tracts of the Peninsular India. Between the successive lava flows are preserved the remains of the terrestrial life of the intervening period in the intertrappean paludine formations, of which several fossiliferous horizons have been traced in the Deccan. These Intertrappean beds have long been known to contain a well advanced type of fossil flora (11) of angiospermous affinities, which, however, has received little attention from the systematic botanists so far.

Of the few plant-bearing localities known in the Central Provinces, Mohgaon Kalan in Chhindwara district, has yielded a varied and nicely petrified angiospermous flora consisting of numerous specimens of stems, roots, fruits, and leaf impressions. Of these, palms constitute a large proportion while the rest belong to several dicotyledonous families. Only a small portion of this material has so far been worked out by the author (8, 9) and in this article he proposes to describe the anatomical details of a well petrified dicotyledonous wood specimen from this collection.

This specimen, originally, was briefly described under the name *Parajugloxylon mohgaoense* (10).

General Description

The fossil wood specimen described below is a small portion of a dicotyledonous branch, about 7 cm. long with a roughly circular cross-section, 2·2 cm. in diameter. On the surface, about the middle

of the specimen (Plate XII, Fig. 1) is a prominent knob-like protuberance, 1·2 cm. in diameter representing the scar of a small twig branching out from this. The petrification in cherty silica is excellent and has preserved very clearly the minutest details of the various tissues. The outer layers of bark, however, are seen only at a few places but the general wood-like appearance of the specimen is quite evident. The growth rings as well as the radiating wood rays can be easily seen by the unaided eye. There is no sign of rolling or weathering due to transportation, and this feature corroborates other evidences pointing to the fossilisation in situ.

The Tissue Systems

The *Pith* is highly eccentric due to the unequal growth of the vascular cylinder. In cross-section, it is five sided, irregularly stellate in outline, about 5 mm. along the longest and 2 to 3 mm. along the shortest diameter (Plate XII, Fig. 2). Three of the angles are more prominently drawn out, and the sides are all more or less incurved. Pith is preserved only along one of the sides; while within the empty spaces there are several large clusters of spherical dark masses. *Primary Wood* is well preserved round the pith; it forms a narrow zone composed of radial rows of 5 to 7 xylem elements gradually increasing in size in the centrifugal direction, and separated by narrow parenchymatous tissues. *Secondary Wood,* which is exceedingly well preserved, shows in its abundant development, a mass of thin-walled fibres associated with a little wood parenchyma and with large wood vessels, more or less evenly, though sparsely, distributed within the fibrous elements (Plate XII, Fig. 3).

Growth Rings, of which there are more than four in number, are easily discernible by the naked eye or through a hand lens. Under the microscope, however, they are not so conspicuous and are suggested only by a slight crowding of the vessels and by a somewhat perceptible disturbance in the radial course of the wood rays at the rings. The zones of the various annual rings, again, show a variable thickness of growth, the innermost zone, about 4·5 mm. thick, being by far the broadest, while the succeeding ones are progressively smaller in breadth. The narrow late (summer) wood consists of one to four closely packed vessels, while the broad early (spring) wood contains a number of vessels sparsely distributed in a considerable mass of fibre elements.

Vessels are comparatively large and in the transverse section often occupy the whole space between two adjacent wood rays thus completely interrupting the radial continuity of the tracheid rows. The vessels are often isolated but very commonly occur in pairs, while radial groups of three or four vessels are not infrequent. Moreover, the seasonal variation seems to have had little effect on the size of the vessels. *Wood Fibres* are remarkably well developed, commonly in two to four or more radial rows between every two consecutive wood rays (Plate XII, Fig. 4). *Wood Parenchyma*

appears sparse, occurring round the wood vessels or in solitary, short radial rows within the fibrous mass.

Wood Rays stand out quite prominently due to their gumlike dark cell contents. They are typically uniseriate and appear to originate immediately beyond the metaxylem elements of the primary wood. On careful search only one ray could be detected which while initially uni-seriate, developed into a bi-seriate ray (indicated by* in Plate XII, Fig. 3) but at about the third annual ring, divided into a multi-seriate ray. This again, a little later is split into several uni-and bi-seriate rays separated by intervening rows of fibres. This singular heterogeneous ray may possibly represent a leaf-trace, as seems very likely since the ray starts from near the most prominent angle of the pith. The rays in general are several tracheids apart and very often run closely touching the radial walls of the vessels. The individual rays range from 6 to 20 cells in height, 12 to 13 cells high being the commonest type (Plate XIII, Fig. 3).

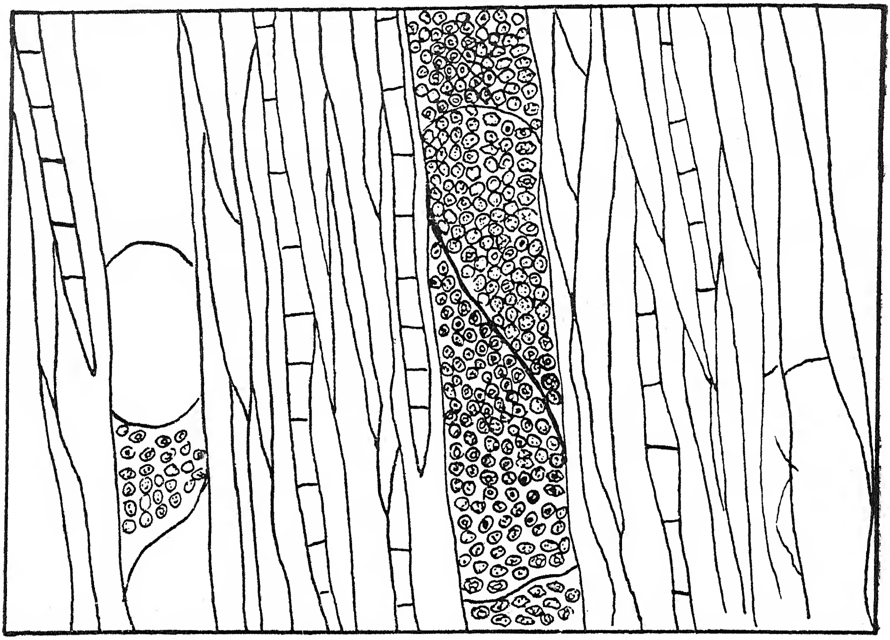
No section shows any of the outer tissue systems and as such nothing can be ascertained as regards the nature of these tissues nor of the behaviour of the wood rays when passing through these outer systems.

The Tissue Elements

Pith elements are thin-walled with roundish, oval or polygonal outline partly overlapping the adjacent cells and frequently leaving intercellular spaces of various sizes (Plate XII, Fig. 2). The inner pith cells average about 0·15 mm. while the outer cells near the primary wood zone are appreciably smaller in size. The products of secretion occur in the empty portions of the pith as massive clusters of large, dark-brown globular crystals and may originally be sphaerites of calcium oxalate.

Primary Wood consists of slightly thick-walled, squarish or rectangular protoxylem elements distinguished in the radial section by their well-marked annular and spiral bands of thickening (Plate XIII, Fig. 1). Next to these are a few metaxylem vessels with distinct reticulations, which gradually merge into the secondary vessels of pitted type. *The Secondary Wood Vessels,* in transverse section, are comparatively large, oval or slightly irregular in outline and average about 0·1 mm. in diameter. When, however, two or more vessels occur together in radial groups, they are appreciably compressed in radial direction. They are on an average 0·45 mm. long. Their walls, especially in contact with other vessels, show distinctly vestured type of pits arranged in several, nearly vertical rows (Text-fig. 1). The occurrence of vestured pits on vessel-walls is specially interesting. They were first described by Dutailly and Jonsson as sieve-like perforated pit membrane but were lately explained by I. W. Bailey (2)

as being due to minute outgrowths projecting from free surfaces of the secondary walls. They occur in only a few families. The end-walls of the vessels have perforations of vestured or simple bordered



Text-fig. 1. *D. mohgaoense*: Radial long, section showing Vessels v, with vestured and simple bordered pits; Tracheides f; and Wood rays r. × 200.

type, scalariform perforations being very rare. In some vessels the end-walls are fairly long, tapering on one side while in others they show short and more or less abrupt terminations. *Tyloses* are of very common occurrence as is clearly observed in longitudinal sections. *Wood Fibres* in transverse section are rounded or slightly compressed radially or tangentially when they tend to be squarish or rectangular in outline. They are all thin-walled and show very little variation in size, being on the whole about 0·02 mm. in diameter. In vertical section, they are pretty long with pointed tapering ends and often show simple type of pitting, more clearly when they are in contact with wood ray cells. *Wood Ray Cells* are mostly radially longer than broad, while the vertical height varies within wide limits. Cells of some of the limiting radial rows are often more than three times as high as long while those of some of the middle radial rows are twice as long as high (Plate XIII, Fig. 2). They are usually perfectly rectangular in vertical section with sieve-like perforated tangential walls, but their transverse walls are quite imperforate. Their radial walls frequently show closely but minutely pitted appearance, more clearly when adjoining the vessels.

Comparison

In the present state of our knowledge, incomplete as it admittedly is, of the anatomical basis of classification of dicotyledonous plants, it is difficult, if not impossible, to assign a decorticated fossil stem fragment to its correct place in the natural system of plant classification. It is not the intention of the author to discuss here the affinities of the fossil stem but simply to put on record a type of stem structure obtained in the Intertrappean beds of the Deccan and to leave the problem of classification to more competent hands of systematic botanists. He may however indicate a few possible comparisons without laying much stress on their innate value.

The important structural features of the wood of the fossil specimen, detailed above, are such as are very commonly met with in a large number of dicotyledonous families and form a sort of generalised type of wood structure comparable to, but differing from Bencroft's Generalised type (4) in the larger pore dimensions and in the thin-walled nature of the wood fibres. The occurrence of vestured pits on vessel walls, however, is a very significant feature. These pits are reported (3) in the secondary wood of genera of about twenty dicotyledonous families, but they occur as distinctive characters in only a few families, *viz.*, Combretaceae, Lythraceae, Melastomaceae, Myrtaceae (in part), Leguminoseae, Polygonaceae, and Vochysiaceae. The last named family differs from the fossil wood in having broader medullary rays and abundant wood parenchyma, while the others show a fairly large degree of similarity in the wood characters.

Besides these, other families, which, though devoid of vestured pits, show a certain degree of approximation in the fossil wood characters, are Ebenaceae, Sapindaceae, Anacardiaceae, Myristicaceae, Juglandaceae, and a few families of the Orders Geraniales, Contortae and Tubiflorae. There are, however, certain important characters which serve to differentiate most of the above families from the fossil wood; for example, the predominance of bordered pitting of the wood fibres in members of Contortae and Tubiflorae; abundance of wood parenchyma in Ebenaceae, Juglandaceae, Leguminoseae and in nearly all the members of Geraniales; the occurrence of scalariform perforations of vessels in Selagineae and Myristicaceae; thick walled wood fibres in Sapindaceae; and simple pitting of vessel walls in Anacardiaceae.

From this brief comparison, it appears to the author that the fossil specimen has its nearest relationship among certain members of the Myrtales, an order well represented in fossil state since the Cretaceous. Amongst these the family Myrtaceae differs from the fossil wood in sometimes having scalariform perforations in the vessel ends and bordered pittings on wood fibres, as also in having at times a little tangential wood parenchyma; Melastomaceae has

usually smaller pore dimensions and is also characterised by Interxylary (included) Phloem; while Combretaceae and Lythraceae show a much greater measure of agreement in the structure of the wood.

Combretaceae is a fairly old family being represented by a number of leaf and fruit species of fossil genera *Combretum* L., *Terminalia* L. and *Conocarpus* L. (7) in the Tertiaries of Europe. Some leaf impressions from the Mohgaon locality assigned by the present author to the genus *Phyllites* Brongn. due to their incomplete nature, resemble *Combretum* fairly in form and venation but cannot be taken as definite evidence of the presence of the latter in the Indian Tertiaries.

Lythraceae, though known since the Eocene, is poorly represented in fossil state.

When we turn to fossil woods for comparison the problem is much simpler but the lack of literature on the subject which is somewhat dispersed has, unfortunately, very much limited the field for comparison. Among the very few fossil dicotyledonous woods described from India, *Dipterocarpoxylon burmiense* (6) from the Fossil Wood Group of Burma agrees in certain important wood characters but differs strongly in having abundant wood parenchyma in tangential bands. The fossil wood of unknown affinities from the Lower Greensand of Bedfordshire described by Stopes (12) as *Sabulia Scottii* presents considerable similarity to the present specimen in its broad wood characters but reveals several differences in minute anatomy.

It is when we come to another specimen described by Stopes and Fujii (13) as *Jugloxylon Hamaoanum* from the Upper Cretaceous of Japan that a very detailed agreement is obtained. Except for the absence of vestured pits all other characters are obtained in an almost identical manner in the Japanese specimen, and for this reason the present specimen was originally named *Parajugloxylon*. The generic term *Jugloxylon* itself is rather very misleading as it irresistibly suggests an unwarranted affinity with the living *Juglans*, while Bailey's suggestion (1) to use prefix "Para" is not quite enough to avoid the possible misconception. The present author has thought it advisable, following Edward's suggestion (5), to assign the Mohgaon fossil wood provisionally to the genus *Dryoxylon* Schleiden, so long as the true affinities of this specimen remain uncertain. The specific name "mohgaoense" is given after the locality.

Summary

Dryoxylon mohgaoense sp. nov.

This species is founded on a small branch specimen 2·2 cm. in diameter, showing mainly decorticated secondary wood and a scar of further branching.

The wood is characterised by Wood Rays numerous, nearly all uni-seriate, with minutely pitted cells of slightly varying dimensions and perforated tangential walls; Wood Vessels large, more or less round, widely but uniformly distributed, solitary or in pairs, a few in radial groups of 3 or 4, thin walled averaging 0·1 mm. in cross section, lateral walls thickly studded with vestured and often simple bordered pits; Tyloses abundant; Wood Fibres abundant, regularly arranged in 2-6 radial rows between any two wood rays; fibre cells thin-walled, round or squarish about 0·02 mm. in diameter, long tapering and sometimes with simple pits; Wood Parenchyma scanty.

Shows nearest affinity with Combretaceae Horizon; locality: Deccan Intertrappean Beds of Mohgaon, C.P.

Type specimen M/21, in the Geological Museum, Benares Hindu University.

Before concluding the author wishes to express his deep indebtedness to Dr. B. Sahni of Lucknow and to members of the Botanical Department of the Hindu University for the helpful criticism, suggestions and facilities accorded to the author during the work.

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Explanation of Plates

Plate XII

Fig. 1. *Dryoxylon mohgaoense* sp. nov. Photograph of the type specimen showing the branch scar. . . .appr. nat. size.

Fig. 2. Trans. sect. of the same showing outline and part preservation of the Pith. ×9.

Fig. 3. Trans. sect. of the Secondary Wood showing Uni-seriate Wood Rays and the Bi-seriate Ray marked (*). × 55.

Fig. 4. Trans. sect. more highly magnified to show vessels, wood fibres and wood ray cells. × 250.

Plate XIII

Fig. 1. Radial long. sect. showing distinct spiral thickening of the primary xylem elements. × 200.

Fig. 2. Rad. long. sect. showing the course and the height of the wood rays. × 55.

Fig. 3. Tangential sect. showing the height of the various tissue elements. × 55.

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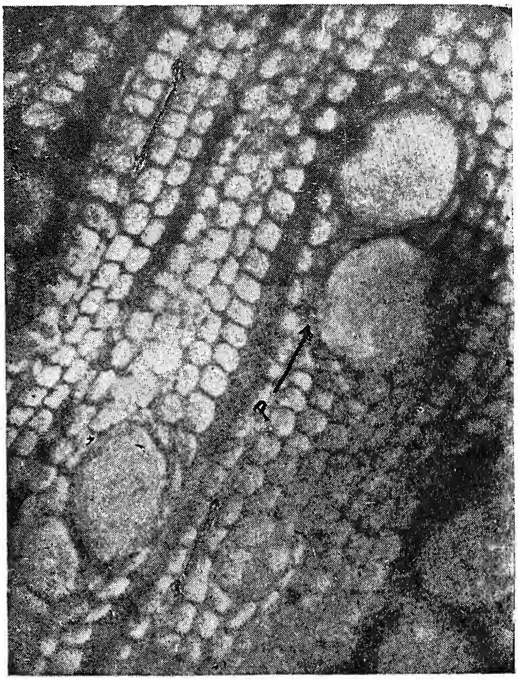

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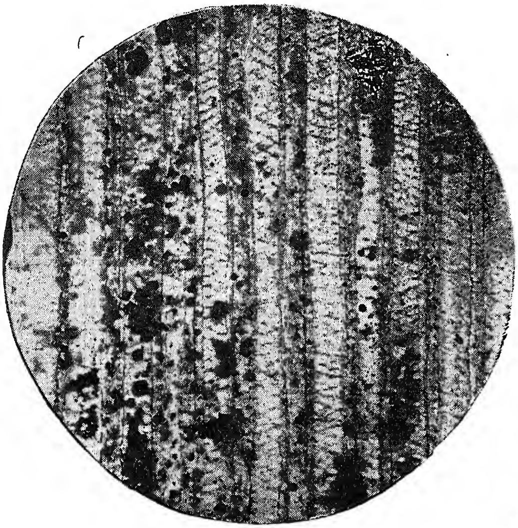
K. P. RHODE—*DRYOXYLON MOHGAOENSE* SP. NOV.



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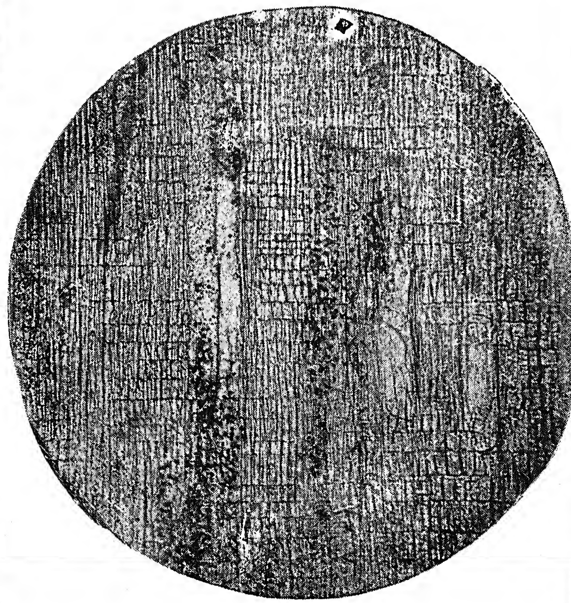

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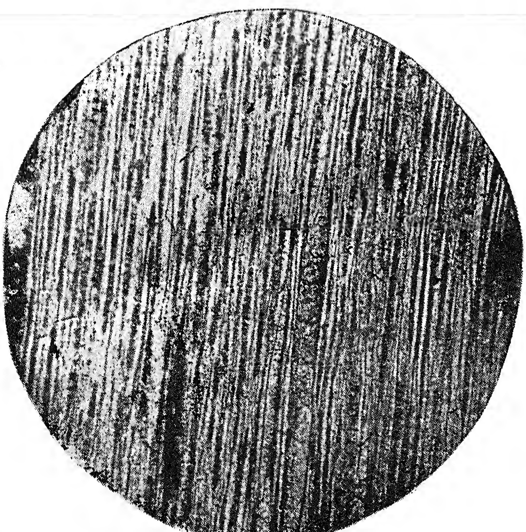

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K. P. RHODE—*DRYOXYLON MOHGAOENSE* SP. NOV.

SORGHUM PAPYRASCENS STAPF.

BY

G. N. RANGASWAMI AYYANGAR, B.A., I.A.S.

Millets Specialist, Agricultural Research Institute, Coimbatore

AND

V. PANDURANGA RAO, M.A.

Assistant, Millets Breeding Station, Coimbatore

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Sorghum papyrascens Stapf. belongs, according to the author of the species, to a group of cultivated sorghums characterised by the existence of papery glumes, of which *Sorghum melaleucum* Stapf. is another. In Grain Sorghums the glumes are coriaceous, often cushiony and sometimes with a transverse wrinkle, all of which serve as devices to clip up and keep in position the free developing grain, a good bit of which emerges out of the glume leaving barely its base inside it. The pedicelled spikelets are longish and not coriaceous. They do not bear grains and most of them have not anthers even. In sessile spikelets the glumes are small and characteristically different in texture from the glumes of pedicelled spikelets. A differentiation has gone on between the two sets of glumes befitting the sessile ones to their rôle. According to the races in which this specialization has taken place, there are minor differences in the shape of the glume of the sessile spikelets, some of which have proved heritable. Graham (1915) records that the short glume is a simple dominant to the long glume. Vinall and Cron (1921) find that the broad truncated glume of Milo is a simple dominant to the ovate, rather acute, tip of Feterita. These differences in glume shape and size, that have been reported as heritable, are within the Grain Sorghums.

In *Sorghum papyrascens* the whole glume becomes papery, loses the characteristic coriaceousness of the glumes of the Grain Sorghums and becomes, as it were, a grain bearing edition of the glumes of pedicelled spikelets, only sessile, so that the striking dissimilarity between the glumes of the pedicelled and sessile spikelets of the Grain Sorghums gives place to a similarity in the general shape of the glumes, the difference being merely in size (Plate XV). It looks as if the factors that have through years contributed to the building up of the Grain Sorghum glume have collapsed and given place to the original primitive, long, papery

glume. There is a strong suspicion that this type of a glume is mutational in origin. Prain's references to "mature panicles only known," and "meagre specimens seen" lend weight to this suspicion. In parts of the Deccan where the Grain Sorghum, *Sorghum cernuum* Hort. (the nearest sorghum in affinity to this *papyrascens*) is grown, one meets with isolated occurrences of this *papyrascens* type, in a good sorghum crop. It should be noted that in *S. cernuum* the top half of the glume is papery. The name, "Nakka Jonna"—fox-sorghum—that has in one place been given to this *papyrascens* type of sorghum, is connotative of its probable mutational origin. At the Millets Breeding Station, Coimbatore, there are many varieties of this *papyrascens* received from Africa and North India. Most of these are characterised by a lightness of weight and an absence of the usual heaviness associated with Grain Sorghums with similarly shaped ear-heads. They are spurred in appearance and are poor in setting. Counts taken in 48 ear-heads of varied origin show that grain setting ranges between anything from 30 and 60 per cent. as against the 90 to 100 per cent. of the Grain Sorghum (Plate XIV). It is a matter for doubt whether *S. papyrascens* as such does or could exist as a current cultivated variety. It is possible that under certain climatic conditions more of a type that favours the growth of *S. cernuum*, certain types of *papyrascens* may have a chance of survival as existing varieties after the disturbed equilibrium is favourably restored, but it looks more probable that these marked out mutants have come to the notice of the sorghum breeder more as curious variants in economic varieties than as representatives of cultivated varieties as such. The variations among the allies of this *papyrascens* possibly mark the variations existing in the basic varieties from which they are mutants.

Prain (1917) notes a number of differences between *S. papyrascens* and *S. durra*, typical of the Grain Sorghums, of which the following are the more marked :—

GLUMES.

S. Papyrascens.	*S. durra.*
Papery and transparent throughout..	Coriaceous.
Greenish with greenish tips	Permanently pale.
Obscurely keeled or keel-less	Keeled.

It will be noted that these main differences pertain to the glume alone. To a sorghum breeder accustomed to bulk crops in intensity, the difference between *S. papyrascens* and *S. cernuum* (its nearest ally) will be hardly noticeable till the time of flowering when the *papyrascens* head manifests its characteristic

absence of fullness. Added to this the irregularity in anther emergence marks these out when in full flower. At maturity a chequered disposition of the sparsely set grains in a setting of pointed, big glumes, betrays the existence of these earheads.

In *S. papyrascens* the glume length varies from 7·5 mm. to 10·5 mm. and its width is 2·5 mm. (800 readings), whereas in *S. durra* the length of the glume is about 5 mm. and its width is about 3 mm. A wide range of measurements taken among the many sorghums, both wild and cultivated, point to a progressive increase in glume length towards the wild condition connoting an evolution towards a shortening of this length and a corresponding thickening. The fluctuation in width has been within narrow limits and it is therefore no wonder that in the Grain Sorghums the tendency has been towards rotundity and thickening.

An absence of this coriaceous and cushiony condition of the glumes in *S. papyrascens* has had its effect on the degeneracy of the lodicules which become very non-functional and highly ciliate, leading to an erratic flowering and an absence of that orderliness recorded in the case of the *Durras* (G.N. Rangaswami Ayyangar and V.P. Rao, 1931). Another effect of these practically keel-less papery glumes with their attendant sterility is a corresponding increase in the anther-bearing of spikelets that are pedicelled, so that with a first wave of anthesis that is jagged in progress, the second fuller wave in antheriferous glumes, adds to the want of orderliness in anthesis and helps to spot out these ear-heads when in flower. It will thus be noticed that long, papery glumes, irregular flowering and poor setting are the characteristics associated with *S. papyrascens.* The rare occurrence of vivipary (G. N. Rangaswami Ayyangar and V. P. Rao, 1935) and of chlorophyll deficiencies recorded elsewhere (G. N. Rangaswami Ayyangar and M. A. S. Ayyar, 1932) are additional evidences of the primitiveness characterising *S. papyrascens.*

It was suspected whether this sterility could be due to any defect either in the stigma or in the pollen. Many tests made proved that the pollen was perfectly viable and the stigmas responded readily to foreign pollen. Any defects leading to this sterility are therefore traceable to the papery glumes and not to any inherent deficiency either of the stigma or of pollen.

Crosses have been made between *S. papyrascens* and *S. durra* with the first generation always being *S. durra* showing the recessiveness of the *papyrascens* character group. In the second generation simple mono-hybrid segregations have been obtained between *S. durra* and *S. papyrascens* and are given below. A factor *py* gives a papery glume, and *PY* gives the common coriaceous glume.

It will be seen that this papery glume character with its attendant economic disabilities like irregular flowering and poor

setting has proved a simple recessive to the normal highly evolved Grain Sorghum glume. It is remarkable that a single genic mutation could upset the whole economic organization of an otherwise well built cultivated variety.

SELECTION NO.	Progeny behaviour in the second generation	
Andropogon Sorghum.	S. durra.	S. papyrascens.
A. S. 690	45	14
„ 691	37	14
„ 3127	35	10
„ 3128	41	9
„ CLII	40	22
„ CLVII	52	11
Total (observed) ..	250	80
(calculated) ..	247·5	82·5
	$\chi^2 = 0{\cdot}1$	$P > 0{\cdot}7$

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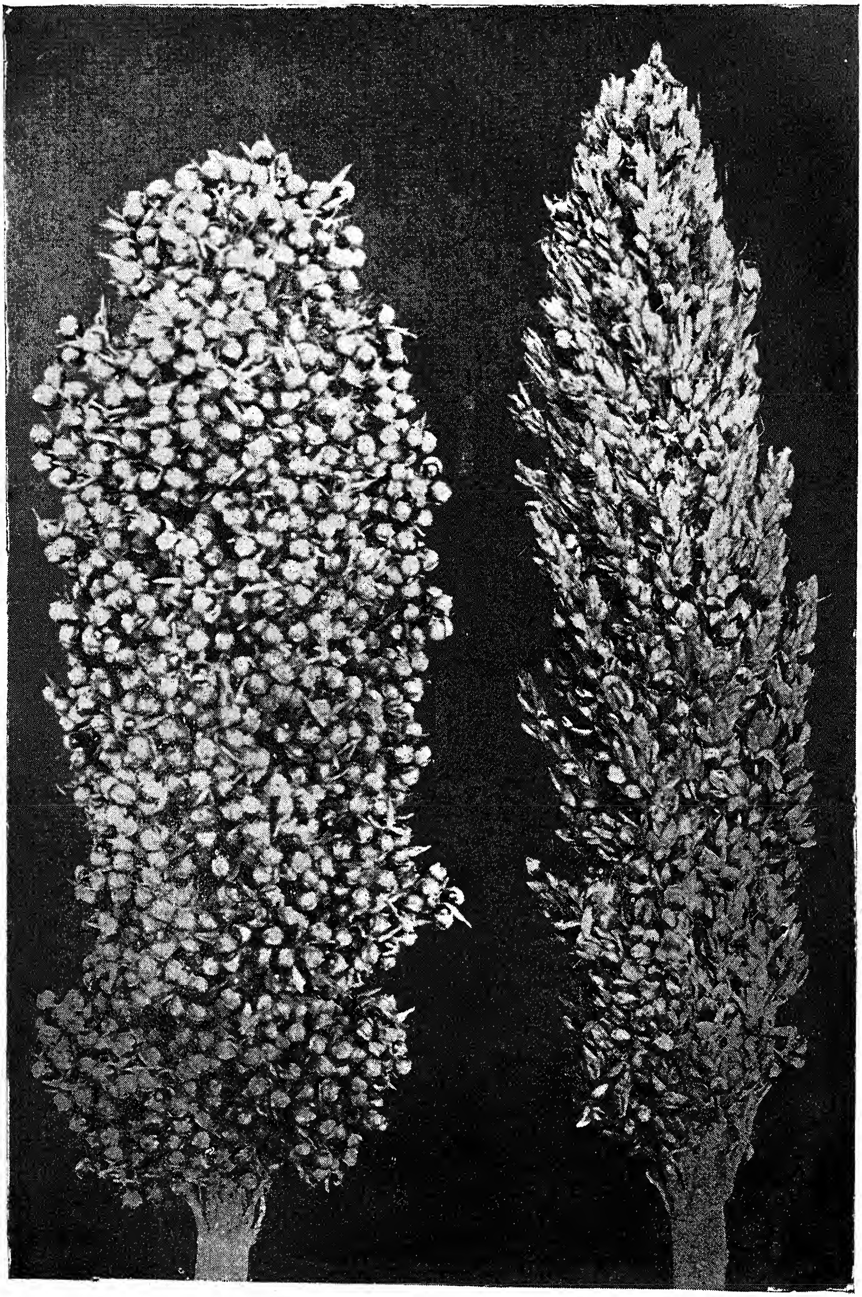

S. durra *S. papyrascens*

G. N. R. AYYANGAR *AND* V. P. RAO—*SORGHUM*.

S. durra *S. papyrascens*

G. N. R. AYYANGAR *AND* V. P. RAO—*SORGHUM.*

ON THE SEED STRUCTURE AND GERMINATION OF *ACANTHUS ILICIFOLIUS* LINN.

BY

D. P. MULLAN

St. Xavier's College, Bombay

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Acanthus ilicifolius Linn. is one of the representatives of the Eastern mangrove. Warming (1883), Goebel (1889), Karsten (1891) and Schimper (1891) have shown the existence of vivipary in the species of the genus *Rhizophora, Bruguiera* and *Ceriops,* where it is especially well-marked, and also, to a less degree, in *Aegiceras* and *Avicennia.* With the exception of these plants, according to Schimper (1903), "in the remaining mangrove plants vivipary does not occur; but the seedlings of some species, in particular those of *Acanthus ilicifolius* and, in America, of *Laguncularia racemosa,* are always further developed than is usual in inland plants". This remark has led to the following observations on the germination of *A. ilicifolius.*

Goebel (1905) defines viviparous plants as "strictly speaking only those in which the embryo germinates without any period of rest and indeed within the fruit as it is attached to the mother plant." The fruit of *A. ilicifolius* is a capsule which, under dry conditions, splits open from the apex to the base. Under moist conditions, however, the seeds germinate within the fruit, with the consequence that before the latter dehisces, it is torn asunder towards the base, the upper part remaining intact. *A. ilicifolius* germinates during the monsoon, as is also the case with other members of the mangrove formation, in the vicinity of the Bombay island (Mullan, 1932). The fruits ripen during July, when the monsoon is well set, and thus have a chance of being continually wetted by the rain. The rain water trickles down the fruit and soaks the persistent calyx segments and the bracts around its base. As a rule, the seeds which are near the base of the fruit are the first to germinate. Under the circumstances, the seeds start to germinate within the fruit and, as the cotyledons of each seed enlarge rapidly and bend away from each other, the basal part of the fruit gets ruptured, allowing the elongating radicles to emerge (Pl. XVI). As the seedlings absorb water greedily and develop further within the fruit, the latter falls off the parent plant, still loosely enveloping the seedlings. If such fruits, or the detached seedlings, happen to fall into the water, as

they may do at high tide, they remain floating for a long time and are ultimately washed ashore. Within a short time of the emergence of the radicle, other roots burst out in all directions from the base of the elongating hypocotyl and fix the seedling to the wet mud. The primary root ceases to grow after a while; the mature root system of the plant is thus adventitious and is supplanted later by the stilt-roots arising from the stems. The few fruits which ripen late, when the monsoon has abated, dehisce from above downwards and discharge the seeds. Thus the successful germination of the seeds within the fruit depends upon the continual wetting of the latter by the rain. Joshi (1932) has recorded similar germination of seeds on the parent plants, during the wet season, in the case of two halophytes of the Chenopodiaceæ.

As the fruit ripens, the epidermal cells of the pericarp get thickened and lignified. At maturity, with the exception of the few cells surrounding each stoma, the whole epidermis gets thickened (Fig. 2). When the fruit is wetted by the rain it may be through these thin-walled cells around the stomata that the water finds an entrance. The rest of the pericarp is made up of roundish polygonal cells with prominent intercellular spaces; the innermost 3-4 layers hold mucilage.

The seeds are invested by a lax, soft, silvery white testa, which appears wrinkled in the dry seeds, forming papillae all over the surface. Towards the end where the radicle emerges, the testa forms a number of multicellular hairs. The seed coat is composed of a single layer of large, more or less isodiametric or somewhat elongated cells. The lateral walls are pitted and very feebly lignified, while the outer and inner walls are thin, transparent and are strengthened by unlignified bands arranged, more or less, as in the reticulate type of thickening (Fig. 3). The basal cells of the multicellular hairs are constructed on the same plan as that of the testa, while the cells at the distal ends are feebly pitted (Fig. 4). The cells of the hairs and those of the seed coat contain nothing but air, hence the silvery white appearance of the latter. The peculiar structure of the cells, the exposure of maximum surface by the formation of papillae and hairs show that the testa must be regarded as an absorbing tissue. As a matter of fact the seed coat and the hairs greedily absorb water.

The cotyledons are cordate in shape. The epidermis, in surface view, is composed of thin-walled, polygonal cells with straight lateral walls. On the lower surface, *i.e.*, the one which is in contact with the testa, the cuticle is feebly developed. Stomata and hydathodes occur on both the surfaces of the cotyledons, being less numerous on the lower surface. The hydathodes resemble those of the mature leaf of the plant (Mullan, 1931) and occur singly or in groups of two or three, the head being composed of 4-8 cells (Fig. 5). The guard cells of the stoma are accompanied by subsidiary cells placed transversely to the pore, as in the mature leaf (Fig. 6). The upper epidermis is followed by 5-6 layers of cells

which, after germination, rapidly elongate and form a palisade-like tissue in the seedling (Fig. 1). The tissue beneath the lower epidermis is composed of loosely-arranged, rounded cells with large, schizogenously-formed air-spaces. The latter are all confined to the lower half of the expanded cotyledons. The air-spaces enlarge considerably on germination; this is correlated with the fact that the

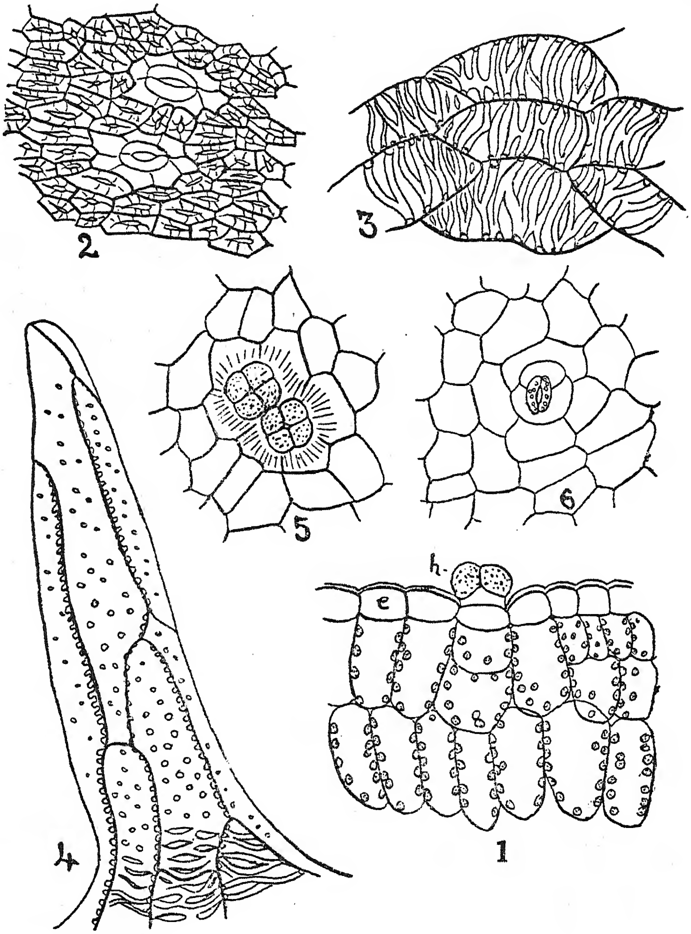

Fig. 1. T. S. part of a cotyledon: *e*, upper epidermis; *h*, hydathode (×120). Fig. 2. Fruit wall, in surface view. (×120). Fig. 3. Cells of the testa, in surface view. (×120). Fig. 4. A hair on the seed coat. (×120). Fig. 5. Hydathodes on the upper surface of the cotyledon. (×120). Fig. 6. Upper epidermis of the cotyledon, showing a stoma. (×120).

seedlings are able to float for a far longer period than the seeds. It is mainly due to these air-spaces in the cotyledons that the seedlings of *A. ilicifolius* are able to float and are dispersed by the tides, as is the case with the seedlings and seeds of other strand plants (Schimper, 1891). Anthocyanin occurs in the sub-epidermal layers, being more pronounced, at the initial stage of germination, on the lower, *i.e.,* the more exposed surface, of the cotyledons. Mucilage and oil occur abundantly in the cotyledons, the oil disappearing as germination proceeds. A peculiarity of the seeds is that the cotyledons are green even while the seeds are enclosed in the fruit. This is a common characteristic of other viviparous mangroves and seeds which germinate in a short time.

Stomata do not occur on the hypocotyl and epicotyl of the mature seedling; hydathodes are present on these parts. In both the hypocotyl and the epicotyl, the inner cortex is traversed by prominent schizogenously-formed lacunae. The structure of the first leaves resembles that of the mature ones (Mullan, 1932). The primary root shows a lacunar cortex and, in seedlings still attached to the parent plant, the outer cells hold chloroplasts.

Summary

When continually wetted by the rain, the seeds of *Acanthus ilicifolius* Linn. begin to germinate within the fruit while still attached to the parent plant.

The structure of the seed coat resembles that of an absorbing tissue. The seedlings are dispersed by water, owing to the presence of air-spaces in the cotyledons, hypocotyl and epicotyl.

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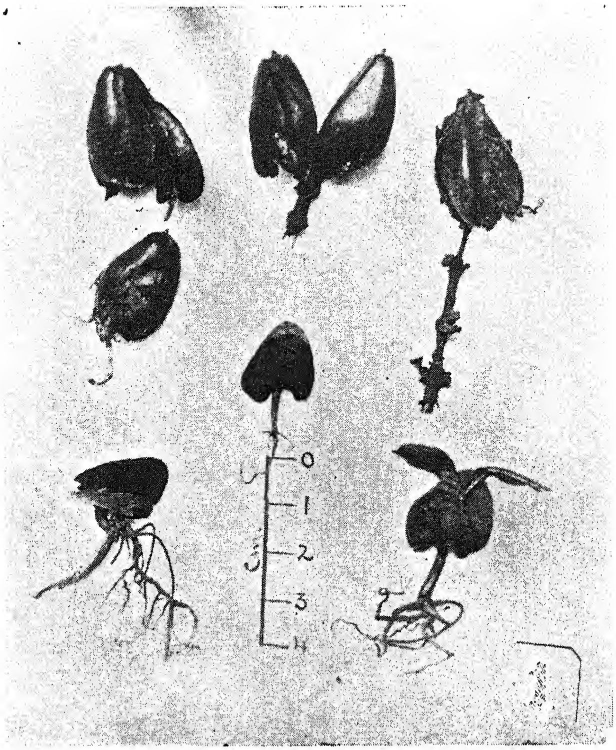
Explanation of Plate XVI

Acanthus ilicifolius Linn. Photograph showing the stages in germination.



D. P. MULLAN—*ACANTHUS ILICIFOLIUS* LINN.

RECENTLY INTRODUCED OR OTHERWISE IMPERFECTLY KNOWN PLANTS FROM THE UPPER GANGETIC PLAIN

BY

MUKAT BEHARI RAIZADA, M.SC.

Forest Research Institute, Dehra Dun

Part II

(Continued from Vol. XIV, No. 4, 1935, pp. 339-348)

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Leguminosae

Psoralea plicata Delile; Fl. Br. Ind. ii, 103.

'Ajmer, A. E. Laurie!'

A low copiously-branched undershrub 1-2 feet high. Leaves trifoliolate. Racemes short-peduncled 2-3 in. long. Flowers 0·2 in. long, solitary or in fascicles of 2 or 3. Petals yellow. Pod 0·2 in. long ellipsoid, densely hairy, completely enclosed in the accrescent calyx which becomes membranous and many-nerved. Fl. April.

Tephrosia Hamiltonii J. R. Drumm. in Gamble, Flora Madras ii (1918), 318; *T. purpurea* Baker in Fl. Br. Ind. ii, 112 *exparte.*

'Ramnagar, U. P., 1st Nov. 1921, R. S. Hole Dehra Dun Herb. No. 24304!'

'Pawalgarh, Ramnagar div., U.P., 1,400 feet, 14-2-1923, A. E. Osmaston 1222!'

'Haldwani division, U.P., 1,400 feet, 11-4-1925, A. E. Osmaston 1247! An undershrub.'

An erect deciduous undershrub 1—3 feet high with a woody basal portion. Stems angular, somewhat zigzag, more or less densely pubescent. Leaves 1·5-5 in. long. Leaflets 7-17 oblanceolate-oblong, 0·5-1 in. long, usually retuse at the apex, mucronate, minutely adpressed hairy above, silky pubescent beneath, entire. Petiolules 0·05 in. long. Flowers 0·3—0·5 in. long, rose coloured or bright pink, in fascicles or pairs on the rachis of terminal or leaf-opposed raceme, 1-7 in. long; pedicels in flower about 0·15 in. long usually much exceeding the linear-subulate bracts. Calyx and back of standard puberulous, remainder of corolla glabrous. Pod 1-1·5 in.

long, somewhat curved near the tip, pilose, becoming glabrous or nearly so when ripe. Seeds 4-7, pale brown mottled darker, about 0·1 in. long. Fl. June-August. Fr. Jan.-Feb.

This species differs from *T. purpurea* mainly by its more erect habit, angled, silky or villous branches and larger flowers.

Alysicarpus Meeboldii Schindler in Fedde Repert. Spec. Nov. Reg. Veget. XXI (1925), 13.

An erect undershrub, stem terete, sparsely adpressed pilose or glabrous. Stipules scarious, striate, lanceolate, acute, glabrous up to ½ in. long. Leaves 1-foliate, petiolate, petiole small, slightly winged, ciliate. Leaves lanceolate or linear-lanceolate, thin, glabrous above, strigose beneath up to 5 in. long ¼ in. broad, nerves not prominent. Raceme terminal, laxly cylindrical about 9 in. long. Flowers pedicelled, pedicels glabrous. Calyx almost 4-fid to the base, sparsely ciliate or almost glabrous. Corolla shorter than calyx. Pod exceeding the calyx, jointed. Joints 4-5, prominently marked with transverse ribs.

Etawah, 28·11·86 Duthie 6366!

This species is, I believe, probably only a more vigorous form of *A. rugosus* DC. *var. ludens* Baker Fl. Br. Ind. ii, 159 and hardly specifically distinct.

Clitoria biflora Dalz.; Fl. Br. Ind. ii, 208.

'Bidholi, Dehra Dun, 4-9-1922, Sohanlal Dehra Dun Herb. No. 28454! Fl. blue-lilac.'

A herbaceous climber, stems angular. Leaves imparipinnate, leaflets 5, membranous, the terminal one largest, 1-3 by ½-1½ in. variable in shape, broadly elliptic-oblong. Flowers in axillary 2-flowered racemes; bracts linear-lanceolate, subulate. Corolla 1 in. long, blue. Pod 1-2 by ¼ in. flat, reticulately veined, pubescent. Seeds 5-6.

Acacia ferruginea DC.; Fl. Br. Ind. ii, 295.

'Donda forest, Banda. Divisional Forest Officer!'

A moderate-sized tree with rough grey bark. Spines stipular, dark brown, sometimes absent. Rachis with one gland towards the base and one between the uppermost pinnae; pinnae 2-5 pairs; leaflets 10-20 pairs, 0·25-0·35 in. long. Spikes dense 3-4 in. long. Corolla yellow. Pod 4-5 in. by 0·75-1·2 in. stipitate, glabrous 4-6 seeded. Fl. March-April. Fr. November-January.

Acacia lenticularis Ham.; Fl. Br. Ind. ii, 296.

'Pilibhit, Sri Ram, 20-4-1919, Dehra Dun Herb. No. 52627! A small tree.'

'Jaulasal Haldwani div. U.P. 800 feet. 29-11-25, A. E. Osmaston 1275! A medium sized tree.'

A medium sized tree up to 60 feet high. Branches armed with pairs of slightly recurved compressed stipular spines. Rachis 5-7 in. long, with a gland below the pinnae. Pinnae 2-5 pairs, 2-5 in. long. Leaflets 6-12 pairs 0·7-1·2 by 0·3-0·5 in. (much larger than in any other species). Flowers white, in dense pedunculate axillary spikes 3-5 in. long and about 0·5 in. diameter. Pod flat, straight, 4-9 by 1-1·5 in. glabrous, seeds 4-8.

Acacia Donaldi, Haines in Ind. For. XLIII (1917), 88.

A small tree (?) up to 2·5 ft. girth, very rarely sub-scandent. Branches with usually 5 lines of minute prickles, twigs finely pubescent, usually armed with short recurved prickles but stipular spines absent or rudimentary. Leaf-rachis 3-10 in. (usually 4—5·5 in.) with very short swollen petiole and a flattish or rudimentary gland on rachis immediately above it and between each of the 3-4 upper pinnae, rachis with very small weak prickles on the lower rounded surface. Pinnae 10-27 (usually 16-20) pairs 0·3-0·5 in. apart and extending down the rachis to within half an inch of base of petiole, median 1·5-2 in. long with 25-40 rarely 50 pairs of linear leaflets 0·25-0·5 in. by 0·03-0·05 in. Flower heads white or cream coloured about 0·5 in. diameter on peduncles 0·58-0·8 in. long usually 3-nate in the axils of bracts. Calyx 0·14 in. almost glabrous 5-nerved with acute lobes. Corolla quite free from calyx, glabrous 0·17-0·19 in. long. Stamens very shortly connate at extreme base and also adnate to base of corolla. Ovary sericeous with long stipes 0·08 in. long. Pods green to pale yellow and whitish-brown, ultimately grey, rather turgid when unripe up to 0·25 in. thick, base attenuate but pedicel if any not exceeding 0·2 in.

Saugor, August 1916, D. O. Witt!

Rosaceae

Pygeum acuminatum Colebr.; Fl. Br. Ind. ii, 318.

'Bhargot Nalla, Ḥaldwani division, U.P. 2,000 feet, Jan. 1922, H. G. Champion Dehra Dun Herb. No. 25194!'

A small evergreen tree with elliptic or ovate-oblong, entire leaves and yellowish-green flowers in axillary tomentose racemes 2-5 in. long. Calyx tomentose. Drupe transversely oblong 0·6-0·7 in. on the longer diameter, with a shallow median furrow, somewhat woody.

This species was recently collected by Mr. H. G. Champion in the Bhargot Nalla of the Haldwani division which is merely a westerly extension of its previously known distribution. Fl. August. Fr. April-June.

Potentilla Kleiniana W. & A.; Fl. Br. Ind. ii, 359.

'Dehra Dun, in shady places, 15-3-1928, B. L. Gupta Dehra Dun Herb. No. 46135!'

A slender prostrate sparsely silkily hairy annual; leaves digitately 3-5-foliolate, leaflets 5 narrowly obovate, serrate, stipulate; flowers small $\frac{1}{4}$ in. diameter, in terminal panicled cymes; achenes minute, deeply wrinkled.

Combretaceae

Anogeissus coronata Stapf in Kew Bull. 1914, p. 153. Syn. *A. sericea* Brandis *var. nummularia; A. nummularia* King Mss. in Herb. Calc.

This species since it was described by Duthie under *A. sericea* Brand. *var. nummularia* on p. 340 of his Flora has proved to be a distinct species.

'Todgarh, Merwara, Sept. 1884, A. E. Lowrie!'

'Merwara, 7-1-86, J. F. Duthie 4663!'

'Indore, Feb. 1910, W. F. Biscoe!'

'Rampura division, Indore State, 17th Nov. 1911, A. B. Pande!'

Combretum ovalifolium Roxb.; Fl. Br. Ind. ii, 458.

'Deori Range, Saugor, 26-2-1915, D. O. Witt!'

A large sarmentose or climbing shrub with elliptic or oval leaves 2·5-4·5 in. long. Spikes 0·5-1·5 in. often racemose on a common rachis and frequently by the fall of the leaves appearing copiously panicled. Fl. 4-merous. Fr. 4-winged. There are no white foliaceous bracts. on the panicle. Fl. Feb.-April. Fr. May.

Passifloraceae

Passiflora foetida Linn. Sp. Pl. (1753), 959; Bot. Mag. t. 2619; Fl. Br. Ind. ii, 599.

A slender foetid-smelling climber with palmately 3-lobed leaves 1·5-2·5 in. long, ciliate and denticulate with gland-tipped setaceous hairs. Stipules laciniate with gland-tipped segments. Peduncles two, below the petiole, opposite, one fertile bearing a single flower, the other degenerating into a tendril. Sepals 5 about $\frac{1}{2}$ in. on the edge of a very short calyx-tube. Petals 5 about as long, greenish with a purple tinge. Inside the petals a ring of long slender filaments (the outer corona), and inside these again another row of shorter one (the inner corona), and inside these again another row of much shorter ones. Ovary and stamens raised upon a stout stalk, which rises from the bottom of a thin-walled cup. Stamens 5, with stout spreading filaments and large anthers attached lightly by the middle of the back. Ovary globular, hairy with 3 large spreading styles dilated at their ends, one-celled with 3 parietal placentas. Fruit like a small green gooseberry containing numerous seeds.

A native of the West Indies but now completely naturalized in Dehra Dun and several other localities in the Upper Gangetic Plain. Fl. and Fr. Rainy and cold seasons.

Passiflora suberosa Linn. Sp. Pl. (1753), 958; Fl. Br. Ind. ii, 599.

A small glabrous or pubescent climber with corky bark. Leaves 3-5 in. long including the petiole, 3-nerved at the base, 3-lobed above the middle, glabrous or pubescent on both surfaces. Lobes ovate or ovate lanceolate, acuminate, entire, the middle one longest. Petiole much shorter than the blade, biglandular at or above the middle, glands subsessile. Tendrils simple. Peduncles twin exceeding the petioles, axillary, simple, one-flowered, jointed above the middle. Calyx 5-cleft, lobes lanceolate or linear lanceolate. Corolla wanting. Crown-filaments purple at the base, shorter than sepals. Berry subglobose or oval, purple to black, small containing several rough seeds enveloped in pulp.

A native of Tropical America but now naturalized at Mothronwala, Dehra Dun.

Another species of 'Passion flower,' *P. morifolia* Masters which has only recently been introduced has begun to run wild and will doubtless in a short time become sufficiently common to deserve a place in the flora as much as an indigenous species.

Begoniaceae

Begonia picta Smith; Fl. Br. Ind. ii, 638.

'Bidholi, Dehra Dun, 4th Sept. 1922, Sohan Lal, Dehra Dun Herb. No. 28186!'

A small succulent herb. Leaves roughly hairy above, pubescent beneath, ovate, cordate. Flowers 1-1½ in. diameter. Capsule pubescent about ½ in. broad, one of the wings much longer than the others, upto 1 in. Fl. Rainy season.

Umbelliferae

Apium leptophyllum F. Muller ex Bentham in Fl. Australia iii (1866), 372.

An erect or diffuse, slender, glabrous annual herb 1-2 ft. high. Leaves ternately divided into numerous filiform segments, the lower ones petiolate, the upper sessile, with fewer segments. Umbels at the nodes pedunculate, rarely sessile, of 2-3 slender rays, each with a partial umbel of many flowers on slender pedicels, without involucral bracts. Calyx-teeth inconspicuous. Petals ovate or broad, with a short inflexed tip, the margins not recurved, scarcely imbricate. Disk rather broad, convex, scarcely distinct from the very short style, carpels ovoid 5-ribbed. Ribs of the carpels very prominent and thick, almost corky, separated by very narrow furrows, with one vitta under each furrow.

Dehra Dun. A common weed in cultivated places. Only recently introduced. Parker! Raizada!

With regard to the native country, distribution, etc., of this species vide T. A. Sprague in Journ. Bot. LXI (1923), pp. 129-133.

Psammogeton biternatum Edgew.; Fl. Br. Ind. ii, 719.

'Dayalbagh, Agra, March 1933, M. B. Raizada, Dehra Dun Herb. No. 62014!'

A small annual, pubescent herb. Leaves 1-2-pinnate, segments of the lower leaves ovate pinnatifid into narrow lobes, of the upper narrowly cuneate laciniate. Umbels compound, bracts 3-8 narrowly lanceolate or linear. Calyx teeth obsolete. Petals obovate, whitish. Fruit scarcely $\frac{1}{8}$ in. lanceolate, thinly hairy.

Rubiaceae

Anthocephalus Cadamba Miq.; Fl. Br. Ind. iii, 23.

'Guliapani, Haldwani division, U.P., 800 feet, 14-1-1927, A. E. Osmaston 1332! A tree.'

A medium-sized tree about 60 feet high. Leaves coriaceous, shining and glabrous above, pubescent beneath, 6-12 in. long, 4-6·5 in. broad, elliptic-oblong or ovate. Stipules 0·5-0·6 in. long. Petiole 1-2·5 in. long, terete. Flowers small, orange or yellow, in globose heads which are solitary and terminal and 1-1·75 in. diameter. Corolla 0·5 in. long. Stigma white much exerted. Fruit a globose pseudocarp 2-2·5 in. diameter, yellow when ripe.

Vangueria spinosa Roxb.; Fl. Br. Ind. iii, 136.

'Mandhaulia, Gorakhpur district, 26-4-1898, Harsukh 22349!'

'Domakhand, Gorakhpur, 26-10-1914, D.F.O. Gorakhpur!'

'Tikri forest, Gonda div., 21-5-1918, Sri Ram Dehra Dun Herb. No. 52656! A throny shrub.'

A deciduous, throny shrub. Leaves 2-5 in. long, 1·25-2·75 in. broad, ovate, pubescent on both surfaces. Stipules early deciduous. Flowers 0·2 in. long, globose, greenish, on short peduncled cymes which are axillary or supra-axillary. Fruit a globose drupe 0·7-1 in. diameter with 3-6 smooth, 1-seeded stones.

Paederia foetida Linn.; Fl. Br. Ind. iii, 301.

'Dehra Dun, Oct. 1891, G. A. Gammie!'

'Bindal Nala, Dehra Dun, 16-10-1914, R. S. Hole Dehra Dun Herb. No. 21187!'

'Mothronwala, Dehra Dun, 12-11-1927, B. L. Gupta, Dehra Dun Herb. No. 45150!'

A slender glabrous climber, foetid when bruised. Leaves opposite 2-6 in. long, 1-2·5 in broad, ovate-lanceolate. Stipules interpetiolar, deciduous. Flowers in axillary and terminal 2-3-chotomously branched panicled cymes, 2-6 in. long, puberulous; bracts often foliaceous. Corolla dingy purple. Pyrenes black with a broad pale wing. Fl. May-October.

Compositae

Erigeron linifolius Willd. Sp. Pl. iii (1804), 1955; Fl. Br. Ind. iii, 254.

Dehra Dun and Saharanpur and probably also in other localities.

An erect hirsute herb with leafy stems and branches. Leaves sessile, linear, entire or remotely serrate, 1·5-2·5 in. long, 0·2 in. broad, densely hairy above, villous beneath. Flower heads numerous, subpaniculate, $\frac{1}{3}$-$\frac{1}{2}$ in. diameter. Achenes sparsely silky. Fl. and Fr. Rainy season.

Gamble in Fl. Madras (1921), 683 and Haines in Bot. Bihar and Orissa (1922), 465 call this plant *Conyza ambigua* DC. As the genera *Conyza* and *Erigeron* are defined by Bentham and Hooker in Genera Plantarum and by Hoffmann in Engler, Pflanzenfamilien this Indian plant is an *Erigeron* and not a *Conyza*.

The oldest valid name for this plant under International Rules of Botanical nomenclature would appear to be *Erigeron crispus* Pour in Mem. Acad. Toulouse iii (1788), 318.

Carpesium abrotanoides Linn.; Fl. Br. Ind. iii, 301.

'Dehra Dun, October 1890, J. F. Duthie 10698!'

A nearly glabrous or pubescent stout herb 2-4 feet high. Leaves sessile, lanceolate, 3-5 in. long, narrowed to both ends, entire. Heads discoid, numerous not more than $\frac{1}{4}$ in. diameter, inserted along the whole length of the branches, axillary, nearly sessile or in axillary racemes. Achenes long, smooth, ribbed, tip shortly beaked, glandular.

Emilia sagittata DC.; Syn. *E. flammea* Cass. Fl. Br. Ind. iii, 336.

This species is quoted by S. Garabedian in the Kew Bull. (1924), 143 as occurring at Moradabad (Moradabad, T. Thomson 840). I, however, suspect that this record refers only to cultivated specimens as this plant is commonly cultivated within our area.

Echinops cornigerus DC.; Fl. Br. Ind. iii, 358.

'Ramgarh, District Dehra Dun, October 1924, B. L. Gupta, Dehra Dun Herb. No. 39226! 39227!'

A tall erect thistle-like herb; stems, branches and lower surface of leaves densely white-cottony. Leaves 4-8 in. pinnately divided into broad, flat, lobed and toothed, spiny segments; upper surface cobwebby. Heads compound, terminal, solitary $2\frac{1}{2}$-3 in. diameter with or without projecting spines. Outer involucral bracts

numerous, soft, hair-like, about $\frac{3}{4}$ in. long. Achenes long, hairy, crowned with pappus.

Tithonia diversifolia A. Gray in Proc. Am. Acad. XIX (1883), 5.

A large shrub, 7-8 ft. high. Leaves alternate, 4-10 in. long including the petiole, strongly 3-nerved, 3 or 5-lobed, softly pubescent on both surfaces, narrowed into a marginate petiole nearly as long as the blade. Flower-heads solitary, axillary and terminal, 4 in. across, yellowish-orange in colour, radiate. Peduncle swollen near the flower. Disk-flowers enclosed in a stiff bract. Achenes quadrangular; pappus of scales with 1 or 2 bristles.

Native of Mexico and Central America, but now completely naturalized in the sub-Himalayan tract near Dehra Dun. Fl. Cold season.

Ximenesia encelioides Cav. Icon. ii (1793), 60. Syn. *Verbesina encelioides* Bth. & Hk. f. ex A. Gray in Bot. Calif. i (1878), 350.

An annual herb, stem densely puberulent, much branched. Leaves deltoid-ovate, thin, alternate or the lowest opposite, narrowed at the base into naked or winged-margined petioles, which are often provided with dilated appendages at the base 2-3 in. long, acuminate, coarsely dentate, green and minutely pubescent above, pale and densely canescent beneath. Flower heads peduncled several, 1-2 in. broad, radiate, showy. Involucre hemispheric its bracts lanceolate, canescent; rays 12-15, bright golden-yellow, 3-toothed. Disk-flowers, numerous, perfect, fertile, their achenes obovate, winged, pubescent, their pappus of 2-subulate awns, those of the ray-flowers rugose, thickened, often wingless. Anthers somewhat sagittate at the base. Style branches with slender pubescent appendages.

'Saradhra, Ajmer, September 1884, A. E. Laurie 4712! On sandy soil.'

'Jaipur, 19th June 1932, P. Maheshwari, Dehra Dun Herb. No. 60396!'

This species is indigenous to Tropical America but occurs apparently as an escape from cultivation.

Campanulaceae

Lobelia rosea Wall.; Fl. Br. Ind. iii, 427.

'Mundiapani, Kalagarh division, 2000 feet, 12-3-1926, A. E. Osmaston 1314! A tall stout herb.'

A tall stout herb 4-12 feet high. Leaves subsessile 6-15 in. long, 1·5-2·5 in. broad. Flowers in terminal racemes, crowded. Calyx pilose. Corolla $\frac{3}{4}$ in. white or rose. Anthers usually very hairy on the backs, tips of two lower bearded.

Primulaceae

Lysimachia pyramidalis Wall.; Fl. Br. Ind. iii, 503.

'Near Dehra, August 1882, J. F. Duthie 2583!'

An erect glabrous herb 10-24 in. high. Leaves alternate, nearly sessile, narrowly lanceolate $\frac{1}{2}$-3 in. long, about $\frac{1}{8}$-$\frac{1}{2}$ in. broad, upper ones smaller. Racemes long lax-flowered. Flowers pale-purple; stalks much shorter than their bracts. Calyx as long as corolla. Corolla bell--shaped, $\frac{1}{4}$ in. diameter.

Myrsinaceae

Maesa indica Wall.; Fl. Br. Ind. iii, 509.

'Near Gurkha lines, Dehra Dun, October 1879, W. Gollan!'

'Near Dehra, July 1882, J. F. Duthie 2565!'

A large shrub with long straggling branches. Leaves 3-5 in. long, 1-1·5 in. broad, lanceolate or elliptic-oblong, distinctly sharp-toothed, glabrous. Flowers white, small, in compound racemes much longer than petiole. Corolla rotate. Berry small, globose, pinkish-white when ripe, edible. Fl. December-April. Fr. Cold season.

Ardisia floribunda Wall.; Fl. Br. Ind. iii, 522.

"Birani Naddi, near Dehra Dun, September 1882, J. F. Duthie 2564!'

'Bhalon, Ramnagar division, U.P., 2,200 ft., 26-1-22, A. E. Osmaston 1177! A fairly large climber.'

A large shrub or small tree, young shoots and inflorescence minutely rusty-tomentose. Leaves narrowly oblong-lanceolate, entire, 5-7 in. long, 1-1·25 in. broad, lateral nerves obscure. Flowers small, red, in terminal compound panicles; bracts linear. Calyx-lobes 0·1 in. long, ovate, acute, minutely rusty. Berry deep-red, globose-pentagonal, scarcely depressed, 0·25 in. diameter. Fl. May.

Ebenaceae

Diospyros Holeana Gupta & Kanjilal in Ind. For. L (1924), 255.

A medium-sized tree with dark, rather rough bark exfoliating in small plates. Leaves alternate, elliptic or oblong-elliptic 4-7 in. long 1·5-2·5 in broad, coriaceous, glabrous. Male flowers 3-4 together, subsessile, peduncle 0·1-0·15 in. long ferruginous-tomentose. Calyx brown, pubescent, cup-shaped, teeth 4-5 acute, ciliate. Corolla tubular 0·4-0·5 in. long, densely silky pubescent outside, glabrous within. Stamens 16 in pairs; pistillode rudimentary, villous. Female flowers, axillary, solitary, subsessile. Calyx broadly crateriform, about 0·5 in. across, lobes 4-5 broadly ovate-acute, pubescent. Corolla 0·6 in. long, urceolate, densely brown silky pubescent. Staminodes 11, pointed at the apex. Ovary villous, 6-celled; styles 3. Fruit about 1·2 in. across globose, seated on the accrescent calyx. Fl. April-May. Fr. January.

Sungarah forest, Gonda division, U.P., 23rd May 1919, P. C. Kanjilal 2440! 2441! 2441a!

This species resembles *D. embryopteris* Pers. when not in flower or fruit but differs mainly by the more pubescent flowers, fewer stamens, villous ovary and glabrescent fruit.

Oleaceae

Jasminum auriculatum Vahl.; Fl. Br. Ind. iii, 600.

'Forest near Bant, Bundelkhand, 6-1-1888, J. F. Duthie 6986!'

'Saugor, 4-12-1914, D. O. Witt!'

'Etawah, U. P., 25-8-1921, R. S. Hole, Dehra Dun Herb. No. 25023!'

A dextrorsely climbing shrub with striate and pubescent branches. Leaves 1-3-foliolate, the lateral leaflets mere auricles. Cymes compound, many flowered. Flowers white, fragrant, 0·3-0·4 in. across. Ripe carpels usually 0·2-0·4 in. across, globose, black when ripe. Fl. May-September, Fr. Cold Season. Often cultivated in gardens where it is bushy and sub-erect.

Ligustrum robustum Bl.; Fl. Br. Ind. iii, 614.

'Guliapani, Haldwani division, 900 feet, 6-12-1925, A. E. Osmaston 1283! A small tree.!'

'Chini, Haldwani, U. P., 26-12-1927, R. N. Parker. Dehra Dun Herb. Nos. 45200! 45201! Small tree near water. Stem deeply irregularly fluted.'

A small tree about 30 feet high. Leaves 2-4 in. long, 1-1·5 in. broad, ovate-lanceolate or elliptic. Panicles 6-12 in. long, pyramidal, pubescent or villous. Calyx campanulate, glabrous 0·05 in. long. Corolla-tube equal to the calyx or nearly so. Drupe 0·4-0·5 in. long, narrowly oblong, often slightly oblique. Flowers June-July.

Apocynaceae

Rauwolfia canescens Linn. Sp. Pl. ed. 2 (1762), 303.

A spreading 2-chotomously branched shrub with pubescent branches and white flowers. Leaves usually in two unequal pairs in a whorl, larger 2·5-3·5 in. smaller about 1 in. elliptic-oblong or elliptic-obovate, softly pubescent, not shining, acute, secondary nerves about 12, very fine, spreading; petiole 0·1-0·25 in. with subulate glands. Flowers in 3-4-nate cymes, at first terminal, peduncles 0·2-1 in. long usually 3-5-flowered. Calyx urceolate, pubescent. Corolla tube pubescent 0·2 in. long, lobes rounded, one-fourth the tube. Ovary entire, slightly 2-lobed, cells 2-ovuled. Fruit 0·25 in.

diameter, red, globose, containing 2, 1-seeded stones, seated on the spreading somewhat enlarged calyx.

'Jhamkuiya, Saugor, 12-9-1913, D. O. Witt!'
'Bichpuri, Agra, 3-12-1933, B. P. Paliwal!'

A native of the West Indies, but occurs apparently as an escape from cultivation.

Chonemorpha macrophylla G. Don.; Fl. Br. Ind. iii, 661.

'Near the Robber's Cave, Dehra Dun, 4-11-1923, R. N. Parker Dehra Dun Herb. No. 36771!'

A large climbing shrub with lenticellate branches. Leaves variable, 6-15 in. long, 5-10 in. broad, broadly elliptic, obovate or suborbicular; lateral nerves 10-12 pairs. Flowers large, in erect, terminal racemose, pubescent cymes, 5-9 in. long. Corolla salver-shaped, white, scented, 3 in. or more across. Follicles 9-12 in. long, 0·75 in. broad, slightly divergent at the base, glabrous. Fl. June-July.

Rhynchodia Wallichii Benth.; Fl. Br. Ind. iii, 666.

'Dhamara Range, Pilibhit division, 21-1-1917, Shri Ram 1368! A large climber.'

'Pilibhit division, U.P., 600 ft., 6-11-1928, A. E. Osmaston 1422! A climber, large and woody, milky juice, in swamps.'

A large climber, branches tubercled. Leaves membranous, ovate or elliptic, acuminate, 5-9 in. long, 2-3 in. broad. Flowers showy, white, fragrant 0·7 in. across in short, subterminal corymbose panicles of cymes which are up to 3 in. across. Corolla-tube 0·3 in. long, Follicles about 10-12 in. long, 0·4-0·5 in. broad. Fl. April.

Asclepiadaceae

Asclepias curassavica Linn.; Fl. Br. Ind. iv, 18.

An erect shrub about 2-3 ft. high. Leaves opposite, lanceolate or oblong-lanceolate, membranous, glabrous or slightly pubescent, 2-3·5 in. long. Flowers in axillary umbels 0·3 in. across, orange; peduncle 1 in. long; pedicels 0·7 in. long. Calx 0·1 in. long, cleft to the base, lobes oblong lanceolate. Corolla about 0·3 in. diameter, lobes reflexed in flower, valvate in bud. Corona bright-orange, of 5 erect spoon-shaped processes, adnate to the stipitate staminal column. Staminal-column distinctly stipitate, anthers with inflexed, membranous tips; pollen-masses solitary in each cell, pendulous, flattened, waxy. Follicles solitary, erect 3 in. long, tapering at both ends, pericarp thin. Seed ovoid, 0·2 in. long, dark brown; coma 1·2 in. long. Fl. and Fr. Practically all the year round.

A native of the West Indies but now completely naturalized in many parts of Dehra Dun and Saharanpur districts, chiefly along water-courses.

Sarcostemma brevistigma W. & A.; Fl. Br. Ind. iv, 26.

'Ajmir, September 1884, A. E. Laurie 4742! Trails on the stems of Euphorbia Nivulia (Thor).'

A leafless trailing shrub; stems $\frac{1}{8}$-$\frac{1}{4}$ in. diameter, green, glabrous. Joints 4-8 in. long. Flowers in sessile many-flowered terminal umbels; pedicels $\frac{1}{4}$-$\frac{1}{3}$ in. long, slender, pubescent. Corolla campanulate, pale greenish-white. Style-apex very shortly conical not exserted. Follicles 4-5 in. long, tapering to both ends, slightly divergent when two together.

Sarcostemma intermedium Decaisne; Fl. Br. Ind. iv, 27.

'Ajmir, A. E. Laurie!'

A leafless twining shrub. Flowers in terminal and lateral sessile umbels. Corolla white. Style-apex oblong-fusiform much exserted beyond the anthers. Follicles 3-4 in. long, not narrowed at the base, narrowed towards the tip, not divaricate when two together.

Tylophora exilis Colebr.; Fl. Br. Ind. iv, 44.

'Mothronwala, Dehra Dun, February 1901, U. N. Kanjilal 881!'

'Garjia, Ramnagar division, U.P., 1,500 ft., 23-1-22. A Ranger student per A. E. Osmaston 1189! A climber.'

A slender climber with ovate-oblong or-lanceolate, acuminate, glabrous leaves. Peduncles long, slender, flexuous, simple or branched, bearing few-flowered subsessile umbels; follicles 3-5 in. long, long pointed, membranous, glabrous.

Heterostemma alatum Wight; Fl. Br. Ind. iv, 47.

'Dehra Dun, in ravines, September 1882, J. F. Duthie!'

A twining shrub; branches with two lines of grey hairs. Leaves 3-6 in. long, 2-4 in. broad, ovate-elliptic or oblong; nerves 3-4 pairs, winged beneath. Flowers yellow, about 0·5 in. diameter, usually in racemose cymes. Corolla rotate. Follicles double, divaricate through nearly three right angles and therefore pointing obliquely upwards 3-5 in. long, 0·2-0·3 in. broad, straight, pointed. Fl. Rainy season, Fr. cold season. The record of this species is based on somewhat insufficient material in Herb. Dehra.

Ceropegia macrantha Wight; Fl. Br. Ind. iv, 74.

'West of Body Guard lines, Dehra Dun, August 1881, J. F. Duthie 2001!'

'Kaulagarh, Dehra Dun, 21-7-1929, H. G. Champion, Dehra Dun Herb. No. 49489!'

'Saharanpur, Kheree Ghat, Falconer!'

An extensive rather stout nearly glabrous climber. Leaves 3-5 in. long, very membranous, elliptic-lanceolate, acuminate. Peduncles longer and stouter than the petioles, many-flowered. Sepals filiform 1/3 in. long. Corolla pale, curved, tube narrow, base swollen and forming a long straight beak. Follicles 4-5 in. long.

Boraginaceae

Sericostoma pauciflorum Stocks; Fl. Br. Ind. iv, 175.

'Jaipur, Rajputana, February 1912, R. N. Parker. Dehra Dun Herb. No. 6836! Abundant on dry sandy soil.'

'Jaipur, Rajputana, 19th June, 1932, P. Maheshwari! Used for camel fodder.'

A small straggling undershrub 6-18 in. high. Leaves variable 0·1-0·5 in. long, clothed on both sides but specially beneath with short rigid bulbous-based adpressed hairs. Flowers 0·15 in. across, white, sessile, solitary, axillary or in a short bracteate raceme. Nutlets 0·1 in. long ovoid. Fl. December-February. This species is abundant in Jaipur and characteristic of sandy soil. Probably also occurs in Ajmir.

Convolvulaceae

Evolvulus nummularius Linn. Sp. Pl. ed. 2 (1762), 391.

A small prostrate perennial herb, the stem branched, branches rooting at the nodes, pilose or glabrate. Leaves alternate, exstipulate, very shortly petioled, almost orbicular, subcordate, very sparingly hairy 0·2-0·5 in. long, rounded at the apex. Peduncles 1-flowered axillary much shorter than the leaves. Sepals 5 oblong or oblong-obovate, obtuse, about 0·1 in. long, not enlarged in fruit. Petals 5 connate in a small funnel-shaped corolla, the limb plicate, 5-angled or 5-lobed, pure white. Stamens 5, filaments filiform. Ovary entire, 2-celled; styles 2 free to the base, each deeply 2-cleft. Stigma linear-filiform. Capsule globose 2-4-valved, 1-4 seeded. Seeds glabrous.

'Dehra Dun near R.I.M. (Royal Indian Military) College Swimming Bath, 24-8-1932, R. N. Parker, Dehra Dun Herb. Nos. 59935! 59936!'

'On the lawn in front of the Convocation Hall, F.R.I. Dehra Dun, 20-9-1935, M. B. Raizada 2082! A prostrate weed with white flowers.'

'According to Tiwary (Proc. Ind. Sc. Congress, Allahabad, 1930) this species has recently migrated into Benares.' I have, however, not seen his specimen.

A native of the West Indies but now becoming naturalized in Dehra.

Argyreia Roxburghii Choisy; Fl. Br. Ind. iv, 185.
'Dehra Dun, September 1891, G. A. Gammie!'

'Dehra Dun, 29-8-1907, R. S. Hole!'

A robust twiner, stems hairy. Leaves 3-7 in. diameter, broadly ovate or orbicular-cordate, softly hairy on both surfaces. Peduncles axillary 2-3·5 in. long. Bracts supersistent. Corolla 2·5 in.

long, funnel-shaped, red. Ovary 4-celled. Fl. August-September. This is var. ampla of Fl. Br. Ind.

Argyreia sericea Dalz.; Fl. Br. Ind. iv, 188.

'Rehli, Saugor, 9-8-1913, D.O. Witt!'

A large silky twiner. Leaves ovate, shortly acute, rounded or slightly cordate at base, sparsely hispid above, densely silky beneath, up to 4 in. long, 2·5 in. broad. Bracts linear or oblong, large 1-1·5 in. long, tawny-silky. Sepals unequal, two outer linear-oblong, the inner 3 lanceolate-acuminate. Corolla 2·5 in. tubular-funnel-shaped, pink, hirsute without.

Ipomoea purpurea Roth.; Br. Ind. iv, 200.

A hairy climber with entire, ovate cordate, shortly acuminate, pubescent leaves and showy flowers about 2 in. long with deflexed pedicels, varying in colour from white to pale-blue or purple. It resembles *I. hederacea* Jacq. at first sight but can always be distinguished from it by its smaller and entire leaves and by the sepals not having ligulate tips. It is a native of Tropical America but now naturalized near Dehra Dun. Fl. August-October.

Solanaceae

Solanum torvum Swartz.; Fl. Br. Ind. iv, 234.

'Dehra Dun, common in ravines Raizada!'

A tomentose shrub about 6-10 feet high, branchlets mostly herbaceous with few prickles. Leaves 3-7 in. long, 2-4 in. broad, sparsely stellate tomentose above, densely so beneath; prickles very few, usually only 1 or 2 on the midrib beneath. Flowers in extra-axillary, dense dichotomous cymes, much shorter than the leaves. Corolla white. Berry 0·4-0·5 in. diameter yellow. Fl. December-March.

This species is very similar in appearance to *S. indicum* but can be distinguished from it by the leaves having only 1 or 2 prickles on the mid-rib beneath, denser cymes and flowers which are always white.

Solanum hispidum Pers. Syn. 1, 228.

A prickly shrub about 5-8 ft. high, clothed with ferrugineous stellate tomentum. Leaves 4-8 in. long, 2-5 in. broad, ovate or elliptic, acute, sinuate or coarsely lobed, stellate-tomentose and somewhat rough above, ferrugineous tomentose below, with a few prickles on the midrib; petiole 0·5-1·5 in. long, ferrugineous tomentose. Flowers in short, dense, extra-axillary ferrugineous tomentose cymes on short peduncles. Corolla about 1 in. diameter, white. Berry globose, 0·5 in. diameter.

A native of Peru but now completely naturalized in ravines in Dehra Dun. Fl. Throughout the year.

Nicandra physaloides Gaertn.; Fl. Br. Ind. iv, 240.

'Sahansradhara, Dehra Dun, June 1930, M. B. Raizada, Dehra Dun Herb. No. 53818!'

An annual, erect, glabrous herb 1-3 feet high. Leaves ovate-lanceolate 4-8 in. long, sinuately lobed and toothed. Flowers blue 1-1·5 in. diameter, single on recurved, usually axillary stalks. Berry globose ½ in. diameter, loosely enclosed by the enlarged, membranous, net-veined, 5-angled calyx.

Datura suaveolens H. & B. ex Willd. Enum. Hort. Berol. 227.

A shrub 6-8 ft. high, branches stout. Leaves petioled, 5-8 in. long, elliptic, narrowed at both ends, sub-entire. Flowers white, very sweet scented at night, pendulous; calyx inflated, glabrous, angular with 5 obscure teeth; corolla 10 in. long, 5 in. across, pure white. Anthers crowded together. Fruit a capsule, ·4 in. long, lanceolate or lanceolate-oblong, smooth.

A native of Mexico but now beginning to run wild in wet shady places in Dehra Dun. Fl. April-September.

Nicotiana plumbaginifolia Viv.; Fl. Br. Ind. iv, 246.

An erect annual herb about 2 ft. high, somewhat scabridly hairy, with spreading radical leaves and slender leafy stems. Leaves alternate, sessile, entire, lower obovate spathulate or elliptic-ovate and glabrescent, upper oblong-lanceolate, semi-amplexicaule, acute, hairy. Flowers very slender white or greenish-white, in terminal subpaniculate racemes. Calyx 0·4-0·5 in. tubular, with linear-lanceolate acuminate unequal lobes about as long as the tube. Corolla salver-shaped with slender linear tube slightly widened above, usually greenish-white, about 1·5 in. long, lobes pure white within, spreading, ovate, acute. Stamens attached in the lower part of the corolla-tube, filaments filiform. Capsule ovate glabrous as long as the calyx, 0·25 in. Seeds minutely rugose.

A native of Mexico and the West Indies but now completely naturalized as a weed of waste places in Dehra Dun and several other localities within the area.

Scrophulariaceae

Limnophila Roxburghii G. Don; Fl. Br. Ind. iv, 265.

Nalapani, Dehra Dun, September 1899, Ram Sukh (Duthie's collector) 23023!'

'Mothronwala, Dehra Dun, November 1932, M. B. Raizada Dehra Dun Herb. No. 62167! In marshy places.'

A slightly aromatic annual herb 1-2 feet high. Leaves opposite, petioled, elliptic or ovate 2-3 in. long; nerves many, stout. Flowers sessile, axillary in peduncled heads, rarely solitary. Calyx lobes lanceolate, finely acuminate. Corolla blue-purple.

Vandellia hirsuta Benth.; Fl. Br. Ind. iv, 280.

'Dholkhand, Saharanpur division, 1,400 feet, 16-9-1928, A. E. Osmaston 1396! Flowers white.'

A sparsely hirsute, erect succulent herb. Lower leaves petioled, ovate or oblong obtuse entire or sinuate, upper sessile. Flowers racemed, pedicels exceeding the calyx. Sepals lanceolate, longer than the orbicular capsules.

Gesneraceae

Aeschynanthus maculata Lindl.; Fl. Br. Ind. iv, 339.

'Dehra Dun Falconer!'

An epiphyte; leaves opposite, lanceolate 4 in. long, 1¼ in. broad. Pedicels clustered, calyx ¼ in. lobes lanceolate acute; corolla ¾ in. narrow. This species has not been collected from our area since Falconer's time.

Pedaliaceae

Pedalium Murex Linn.; Fl. Br. Ind. iv, 386.

'Ajmere, 17-10-1889, J. F. Duthie 6802! On sandy ground. Vern. Gokru Kanti.'

'Etawah, U.P., August 1921, R. S. Hole 1728!'

'Jaipur, 14th September 1932, P. Maheshwari!'

A glabrous stout-stemmed herb about one foot high. Leaves opposite, decussate about 1 inch long, oblong-oval irregularly toothed or lobed. Flowers pale-yellow, one in the axil of each of the upper leaves. Fruit a conical capsule with 4 spines.

Acanthaceae

Thunbergia coccinea Wall.; Fl. Br. Ind. iv, 393.

'Pawalgarh, Ramnagar division, 1,400 feet, U.P., 17-2-1923, A. E. Osmaston 1223!'

'Dehra Dun, near Companybagh, 9-12-1918, Sohan Lal, Dehra Dun Herb. No. 20265!'

An extensive climber with long pendulous branches. Leaves 3-5 in. long 1·5-3 in. broad. Flowers scarlet to orange in lax pendulous racemes. Bracts persistent. Capsule 1-1·5 in long, globose, narrowed suddenly into a flat beak. Fl. December-March.

This species is commonly cultivated in gardens and is often met with as an escape from cultivation in ravines, etc.

Strobilanthes glutinosus Nees; Fl. Br. Ind. iv, 364.

'Dehra Dun, 2,500 feet, February 1894, J. S. Gamble 24541!'

A small viscous-hairy aromatic shrub about 3 feet high. Leaves hairy, ovate, about 3 in. long. Flowers pale blue, in short

capitate spikes. Calyx glandular-hairy. Corolla $1\frac{1}{2}$-2 in. long, lower half of the tube cylindric, upper half dilated. Fl. November-February.

Peristrophe speciosa Nees; Fl. Br. Ind. iv, 556.

'Dehra Dun, 2,000 feet, March 1894, J. S. Gamble 24567!'

'Near Lachiwala, Dehra Dun, November 1918, B. L. Gupta, Dehra Dun Herb. No. 20223!'

'Garjia, Ramnagar div., U.P., 1,500 feet, 16-1-22, A. E. Osmaston 1185! An undershrub.'

An undershrub with erect or suberect stems 2-5 feet high. Leaves 4-8 in. long, 2-4 in. wide, elliptic, base cuneately narrowed into the petiole, softly pubescent on both surfaces. Flowers in small bracteate clusters terminating the spreading branches of a large terminal leafy panicle. Corolla magenta pink. Flowers: January-March.

Verbenaceae

Lippia geminata H. B. K.; Fl. Br. Ind. iv. 563.

'Deori Range, Saugor, C.P., 6-1-1914, D.O. Witt Dehra Dun Herb. Nos. 7189! 7190!'

A gregarious shrub 3-5 feet high. Leaves lanceolate closely crenulate or crenate-serrate. Flowers pink, scented in capitate spikes 0·3 in. long elongating to 0·7 in. on axillary peduncles 0·3-0·5 in. Bracts ovate acuminate softly hairy.

Verbena bonariensis Linn.; Fl. Br. Ind. iv, 565.

A tall perennial herb; stem erect, unbranched below, acutely 4-angled, striate, scabrid-pubescent; internodes 2·5-6 in. long. Leaves opposite, sessile, amplexicaul, oblong-lanceolate, acute, stiff, scabrid, rugose above, hispid on the nerves beneath, with margins strongly revolute, sharply serrate in the upper half, nearly entire in the lower, 3-4 in. long, 0·5-0·6 in. broad. Flower spikes in terminal corymbs. Spikes cylindric, dense, bearing numerous bracteate lilac flowers, $\frac{1}{3}-\frac{2}{3}$ in. long $\frac{1}{6}$ in. diameter, bracts lanceolate, acuminate, hispid. Calyx cylindric in flower, slightly dilated below in fruit. Corolla-tube cylindric, pubescent without and within, the upper part 0·2-0·3 in. long. Stamens inserted below the middle of the corolla tube. Fruit enclosed in the dilated calyx.

A native of Brazil but now naturalized near Mothronwala and several other places in Dehra Dun. Fl. August-September.

Callicarpa longifolia Lamk. *var. lanceolaria.;* Fl. Br. Ind. iv. 570.

'Dhanara, Pilibhit, 18-6-1916, Shri Ram 1627! A shrub.'

'Milani, South Kheri, 12-3-1917, Shri Ram, Dehra Dun Herb. No. 52516!'

A shrub, young plants scarfy stellate. Leaves 4·5-6 in. long 1-1·7 in. broad, narrow lanceolate, acuminate, serrulate. Flowers rose or purple on spreading, somewhat lax, cymes. Calyx glabrate, truncate, 0·05 in. long. Corolla 0·1 in. across. Fl. March-August. Fr. June-September.

Premna scandens Roxb. syn. *P. coriacea* Clarke *var. oblonga* Fl. Br. Ind. iv, 573.

'Domakhand, Gorakhpur, 26-10-1914, Divisional Forest Officer, Dehra Dun Herb. 10117! A scandent shrub.'

A large woody climber with pale-brown bark. Leaves 6-8 in. long, 2·7-4·5 in. broad, elliptic, elliptic-oblong or ovate, caudate, entire. Flowers about 0·2 in. across, greenish-white, in large spreading corymbose pubescent panicles up to 8 in. across. Calyx truncate, cupular 0·05 in. long not enlarging in fruit. Corolla about 0·1 in. long. Drupe obovoid 0·15 in. across (immature?)

Vitex leucoxylon Linn. f.; Fl. Br. Ind. iv, 587.

'Jhansi-Rajghat along the Betwa — P. C. Kanjilal.'

A small deciduous tree. Leaves usually digitately 3-5 foliolate. Leaflets 1-3 in. long, ·25-1 in. broad, central largest, coriaceous. Flowers fragrant white about 0·6 in. long, in peduncled compound corymbiform lax dichasia 1·5-4 in. long, Corolla 2-lipped, about 0·45 in. long adpressed pubescent outside. Drupe 0·7 in. long ellipsoid, dark purple seated on the accrescent calyx.

Labiatae

Plectranthus striatus Benth.; Fl. Br. Ind. iv, 618.

'Dehra Dun, 18-10-1897, J. F. Duthie!'

'Dehra Dun, 18-10-1926, B. L. Gupta, Dehra Dun Herb. No. 42596! Calyx, corolla and undersurface of leaves with minute red glands.'

A roughly pubescent herb 6-24 in. high. Leaves 1-4 in. long, 1—2·5 in. broad, ovate, crenate; lower surface gland-dotted. Calyx gland-dotted. Corolla white; tube straight much longer than the calyx.

Mentha piperita Linn.; Fl. Br. Ind. iv, 647.

A perennial, aromatic herb propagating by means of stolons or runners. Stem erect or ascending 1-3 feet high, branched, glabrous. Leaves lanceolate, shortly petioled, sharply serrate, 1-3 in. long. Flowers in thick, terminal spikes 1-3 in. long in fruit; bracts lanceolate, acuminate. Calyx tubular campanulate. Corolla glabrous, purple rarely white.

Native of Europe but now run wild and naturalized along water-courses in Dehra.

Scutellaria angulosa Benth.; Fl. Br. Ind. iv, 669.

'Near Robber's Cave, Dehra Dun, March 1931, M. B. Raizada Dehra Dun Herb. Nos. 56063! 56064!'

A pubescent or thinly hairy shrub-like herb; branches 4-angled Leaves stalked, ovate or lanceolate 1-2 in. long, coarsely crenate. Racemes glandular. Flowers $\frac{3}{4}$-1 in. long, pale-yellow or nearly white, tip tinged with purple.

Teucrium Royleanum Wall.; Fl. Br. Ind. iv, 700.

'Tons Valley, Dehra Dun, 28th April 1930, M. B. Raizada Dehra Dun Herb. No. 52853!'

A tomentose or hairy herb 1-1$\frac{1}{2}$ feet high. Leaves stalked, cordate, ovate or oblong-ovate 1·5-2·5 in. long, crenate or sharply toothed. Racemes seldom more than 2-3 in. long. Flowers about 0·5 in. long, white. Corolla-tube twice as long as the calyx.

Plantaginaceae

Plantago pumila Willd.; Fl. Br. Ind. iv, 707.

'Dubhalwala, Dist. Dehra Dun, 10-3-1922, Sohan Lal Dehra Dun Herb. No. 25539! Near houses.'

A nearly glabrous small herb. Leaves filiform, margins revolute. Spikes axillary, ovoid or subglobose, puberulous; bracts longer than the calyx, corolla lobes finely acuminate.

This is the only record of the occurrence of this species within the area.

(*To be continued*).

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A DEVICE FOR MAINTAINING CONSTANT TEMPERATURE AND HUMIDITY IN A GLASS CHAMBER

BY

P. C. Mallik

Ravenshaw College, Cuttack

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For many purposes and especially in connection with the study of physiology, it is likely to prove useful to build a glass-chamber considerably large to hold several pot plants and other equipments. And if the temperature and humidity inside this chamber could be controlled, at least to some extent, it will prove to be very useful for physiological experiments regarding transpiration and other allied phenomena. In this paper is described the construction of such a chamber with material available in an average laboratory.

The chamber 'K' (Fig. 1) has an internal dimension of 4′ x 3′ x 4′, all the sides excepting the base being constructed of glass plates (better if double). A closed galvanised vessel 'L' with three openings covers the whole of the wooden base of the chamber. Two of the openings serve as inlet and outlet for water and through the other a thermometer is inserted. Water comes to the closed reservoir through the inlet 'N' and siphoned back to the thermostat through the outlet tube 'O'. A dry and wet bulb thermometer could be hanged conveniently in the chamber. Thermograph, potted plants and other apparatus could be placed on the top of the reservoir safely, as it is made very strong and could be used as a work table.

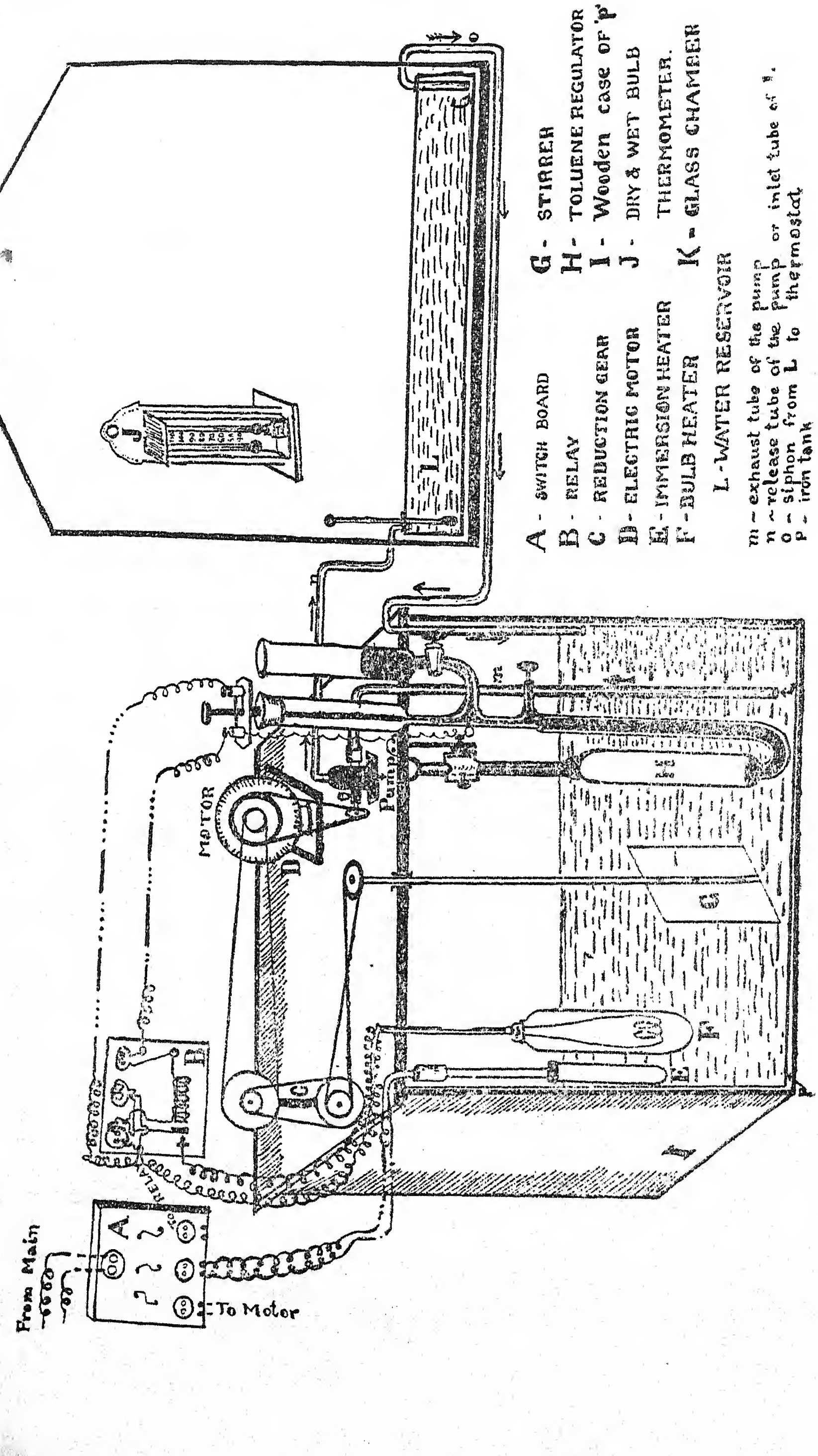

From Main
To Motor
RELAY
MOTOR
Pump
A - SWITCH BOARD
B - RELAY
C - REDUCTION GEAR
D - ELECTRIC MOTOR
E - IMMERSION HEATER
F - BULB HEATER
G - STIRRER
H - TOLUENE REGULATOR
I - Wooden case of 'p'
J - DRY & WET BULB THERMOMETER.
K - GLASS CHAMBER
L - WATER RESERVOIR
m - exhaust tube of the pump
n - release tube of the pump or inlet tube of
o - siphon from L to thermostat
p - iron tank

FIG. 1

A thermostatic reservoir in which the temperature was electrically controlled (by A. Gallenkamp's Electric Heating Outfit) was used as the primary reservoir. Ball-bearing cycle hubs were used very successfully as the axis of the pulleys of the reduction gear which controlled the revolution of the stirrer. To circulate water through the closed reservoir of the glass chamber, Gallenkamp's small Water Circulating Pump was used. The pulley of this pump was made smaller than the pulley of the motor with which this was connected. The revolution of the pulley of the pump was for this reason greater than that of the motor. The force with which the water was driven out of the pump into the closed reservoir through the release tube 'N' was also great. To relieve the tube of such a great tension, a second release tube was also fitted and, by regulating the flow of water through this tube, the flow in the other tube was regulated in such a way that it just neutralised the outflow of water from the reservoir through the siphon 'O'. So the level of water in the reservoir could be made constant with ease. The level of the water inside could be seen directly by the arrangement shown in the adjoining figure (Fig. 2). The long arm of this simple device runs diagonally from lower corner to the higher corner. The water level in this tube indicates the level inside.

The inlet tube 'N' just touches the water level inside the reservoir when it is full and the siphon tube 'O' reaches the bottom, so that the circulation is efficient.

The blackening of the toluene in the thermo-regulator was prevented by shaking it occasionally with a little mercury for a couple of days and taking the filtered toluene. The sparking of the break and make in the mercury column was minimised by inserting one 0·01 microfarad paper condenser and a 15 watt bulb in parallel with the binding screws of the regulator and lastly short-circuiting of the metal tanks was stopped successfully by earthing the water of the thermostat.

To start the thermostat, the switch board is connected with the main and as the motor is started the pump and the stirrer begin their work. The immersion heater 'E' is also connected to the switch board. Water is poured by the pump into the closed reservoir and its level rises. When the tank is nearly full as indicated by the diagonal tube in Fig. 2, the siphon is started. The second release tube from the pump is manipulated till the inflow and outflow of the reservoir become equal. The immersion heater is switched off as the required temperature has been attained. The relay is now connected after the mercury level in the long arm of the toluene regulator is set to position. Circulation of water at a constant temperature goes on from the thermostat to the reservoir and back.

When the temperature in these arrangements is little above the room temperature radiation is less and the glass chamber indicates

a temperature 2°-4° F. lower than the thermostat-temperature. The following readings were noted:—

Temp. of room.	Thermostat-temp. raised upto—	Glass chamber indicated—
Winter:		
87°F	92°F	89°F
80°F	87°F	84°F
82°F	84°F	82°F
Summer:		
97°F	105°F	101°F
100°F	105°F	102°F
106°F	106°F	106°F

But when the temperature difference between the water and the room is greater, the radiation is greater and consequently the temperature difference between the glass chamber and the water of the thermostat is greater.

Temp. of room.	Thermostat-temp.	Chamber indicated.
87°F	100·4°F	95°F
87°F	106·0°F	98°F
80°F	100·0°F	89°F

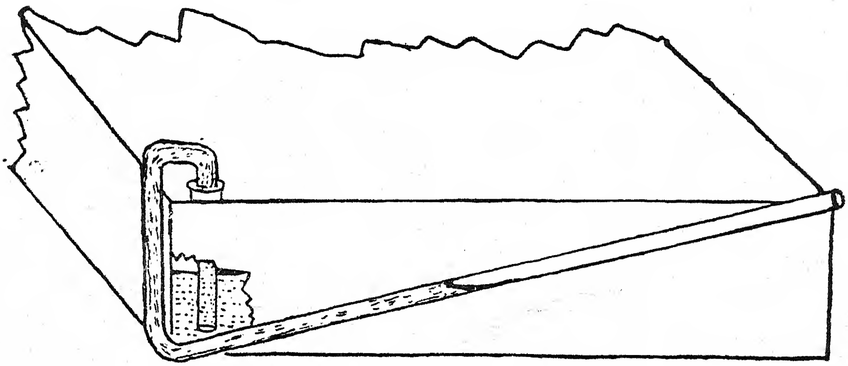


FIG. 2.

When the thermostat is worked for 24 hours the room temperature fluctuates, but in nearly all the cases when the difference of temperature between the atmosphere and the thermostat is within 12° F, the temperature in the chamber remains nearly constant at 6° higher than the atmosphere or lower than the thermostat. But when the thermostat-temp. is raised upto a temperature more than 12° F

higher than the atmosphere and the thermostat is run for 24 hours the chamber-temperature varies as follows:

SEPTEMBER-OCTOBER.

Day-temp.		Night-temp.		Thermostat-temp. raised upto	Chamber-temp. fluctuating within
Max.	Min.	Max.	Min.		
89°F	84°F	84°F	73°F	100°F	90°& 95°F
88°F	82°F	82°F	70°F	100°F	89°& 95°F

The curve drawn in the thermograph during the day-time is practically straight and remains so during the first part of night. As time proceeds the curve bends down, reaching the minimum temperature at 2 a.m. Upward motion begins from about 7 in the morning.

The humidity is controlled by keeping solid rock salt in strong brine in a large open vessel. The following readings were noted:—

Room-temp.	Temperatures in the Chamber Dry-bulb.	Wet-bulb.	Humidity.
87°F	92.5°F	84°F	69.
87°F	94.0°F	85°F	68.
76°F	78.0°F	72°F	66.
78°F	82.0°F	74°F	67.
78°F	84.0°F	76°F	68.

If any other p.c. is required other salts might be used in place of sodium chloride, *e.g.*, if calcium chloride is used 30 p.c. humidity is attained with ease. The readings are given below:—

Room-temp.	Temperatures in the Chamber Dry-bulb.	Wet-bulb.	Humidity.
76°F	87°F	66°F	30.
76°F	78°F	59°F	32.
76°F	80°F	60°F	31.
78°F	88°F	68°F	33.

In conclusion I wish to express my sincere thanks to Prof. P. Parija, M.A. (Cantab), I.E.S., Head of the Department of Botany, Ravenshaw College, Cuttack, for many helpful suggestions. I am also indebted to Dr. M. Sen Gupta, Head of the Department of Physics, Ravenshaw College, Cuttack, for some materials he very kindly supplied for the thermostat and for his suggestions for the improvement of the same.

A NEW TYPE OF ELECTRIC RECORDER FOR PLANT AUTOGRAPHS

BY

C. V. KRISHNA IYENGAR, M.SC.

Department of Botany, University of Mysore

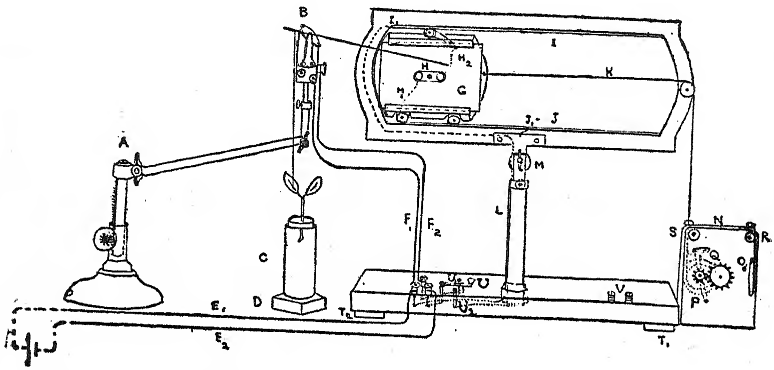
Received for publication on 9th November, 1935

In the course of my experiments on the autonomic and the paratonic movements in plants, I experienced considerable difficulty in recording rapid movements for want of a suitable recorder. The recorders supplied by the scientific firms did not help me much. Sir J. C. Bose (1) has designed several types and, with the help of these, has worked exhaustively on the various kinds of plant movements under different conditions. I found that it was possible to construct with the ordinary materials at hand, a recorder with compactness, efficiency and simplicity of mechanism forming its special features. With slight adjustment it can be made to record either rapid or slow movement. This apparatus has a lever capable of rapid vibrations so characteristic of Bose's Resonant Recorder, the slow movement seen in his Phytograph, and the rocking arrangement of the plate and high magnification found in his High Magnification Crescograph. In combination with the apparatus I had designed in 1929, (3), it is possible to record even photosynthesis in some of the water plants.

Description and working of the Recorder:—The apparatus can be divided into four parts for the sake of description. These are (1) the Electric lever, (2) the Stand with the frame and electric connections, (3) the Electric trolley carrying the smoked glass plate and (4) the Electric Clock. The different parts of these have been labelled in the diagram of the recorder.

Electric Lever:—This consists of a fibre block with an electromagnet and its electric connections, and a light hard lever mounted on special bearings ensuring free movement. It is capable of rapid vibrations independently, while with the interposition of a metronome or the Electric Clock in the circuit even slow movements can be obtained. The electric terminals on the block will enable either kind of movement when connection is given. A fine unspun silk-fibre connects the plant with the lever as in Text-fig. 1.

Stand:—This is composed of a heavy base with rubber legs to minimise mechanical shock. The switch U connects U_1 or U_2 resulting in the vibration of the lever or rocking of the plate mounted on the trolley. The current flows through the rails I and J to which the wires I_1 and J_1 are soldered.



Text-fig. 1.—Diagrammatic representation of the electric recorder.

A. Rack and pinion arrangement. *B*. Electric lever. *C*. Plant. *D*. Base to keep the plant steady. E_1 and E_2. Electric wires from battery. F_1 and F_2. Wires to the electric lever. *G*. Electric trolley. *H*. Electro-magnet in the trolley. H_1 and H_2. Electric wires to the magnet. *I* and *J*. Electrified rails. I_1 and J_1. Wires to the rails. *K*. Thread to draw the trolley carrying the plate. *L*. Stand with the frame. *M*. Nut for tilting arrangement. *N*. Electric clock. *O*. Pin for 'make and break' arrangement. *P*. Gear-block. *Q*. Cog wheel. *R* and *S*. Electric terminals. T_1 and T_2. Rubber legs. *U*. Switch. U_1 and U_2. Terminals for switching on the lever or the trolley. *V*. Terminals for electric stimulation of the plant.

Electric Trolley:—The trolley moves on the rails I and J. The two terminals H_1 and H_2 of the electro-magnet in the trolley have contact with the electrified rails I and J through the wheels. The slow rocking of the glass plate once or twice a minute is brought about by the electric clock placed in the circuit.

Electric Clock:—A strong time-piece is selected for this purpose. Since all the parts are in tact, it performs the usual function of showing time also. It forms the source of power to draw the trolley, the speed of which can be regulated by the gear-block. The contact of the gear-block with Q results in the movement of the trolley. The completion of the circuit through the terminals R and S will enable 'make' and 'break' at intervals.

When the plant movement has to be studied, the plant part is connected to the lever by means of a fine unspun silk-fibre. If rapid movements are to be recorded, the electric lever is allowed to vibrate, while slow movement can be recorded by the interposition of a metronome or the electric clock in the circuit. By this arrangement

the recording point of the lever is made to have momentary contact with the smoked glass plate at short or long time-intervals enabling one to get an efficient record of the plant's activity, since friction has been eliminated by this arrangement. Any speed of the trolley ranging from one to three inches or more per hour can be regulated by the gear-block. Figures 2, 3, 4 and 5 of Plate XVII are some of the records taken to test the efficiency of the recorder. I am sure that students of plant physiology will find this electric recorder very useful in their experiments on plant movements and growth.

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2. DARWIN AND ACTON.—Practical Physiology of Plants. 1925.

3. KRISHNA IYENGAR, C. V.—Apparatus to measure the Photosynthetic activity in some of the water plants. Half-yearly Journal of the Mysore University, Vol. III, No. I, 1929.

4. PALLADIN.—Plant Physiology, edited by B. E. Livingston. 1926.

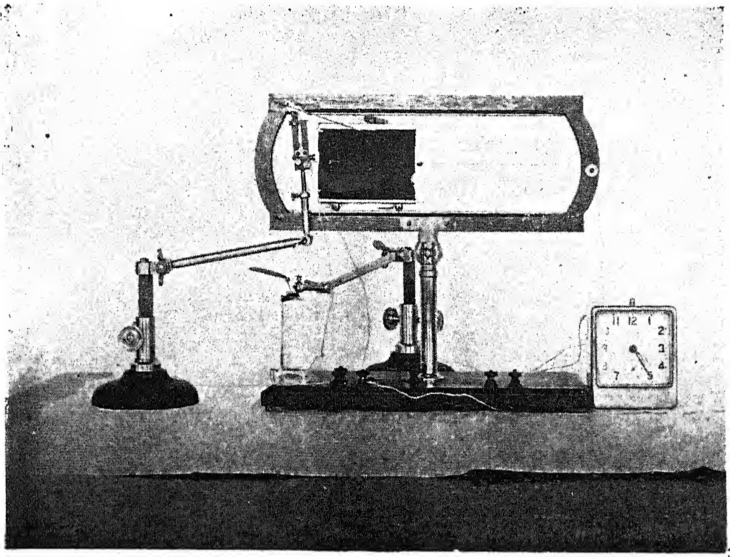
Explanation of Plate XVII

1. Photograph of the recorder.

2. Response record of *Mimosa pudica* leaf under mechanical stimulus.

3, 4. Record of the movement of *Desmodium gyrans* leaflet attached to the plant.

5. Record of the movement of *Desmodium gyrans* leaflet separated from the plant.



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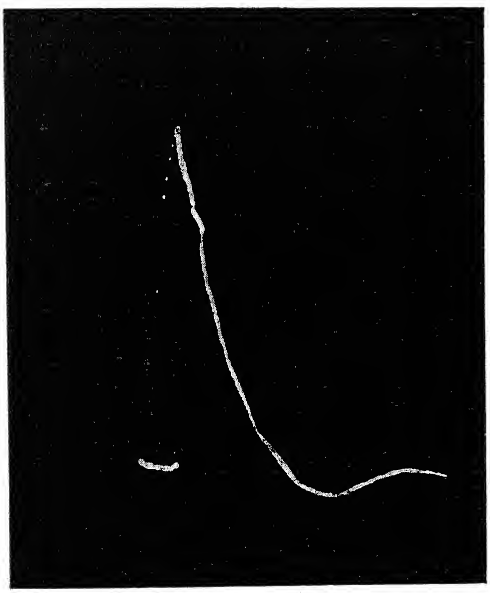

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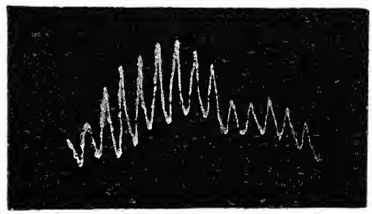

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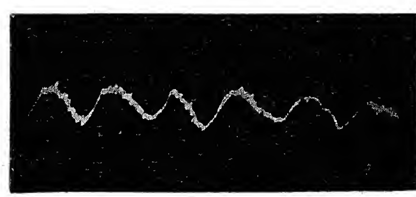


5

C. V. K. IYENGAR—*ELECTRIC RECORDER FOR PLANT AUTOGRAPHS*

C A E [illegible]

ON THE MUCILAGE-GLANDS AND ABSORBING-HAIRS OF *PEDALIUM MUREX* LINN.

BY

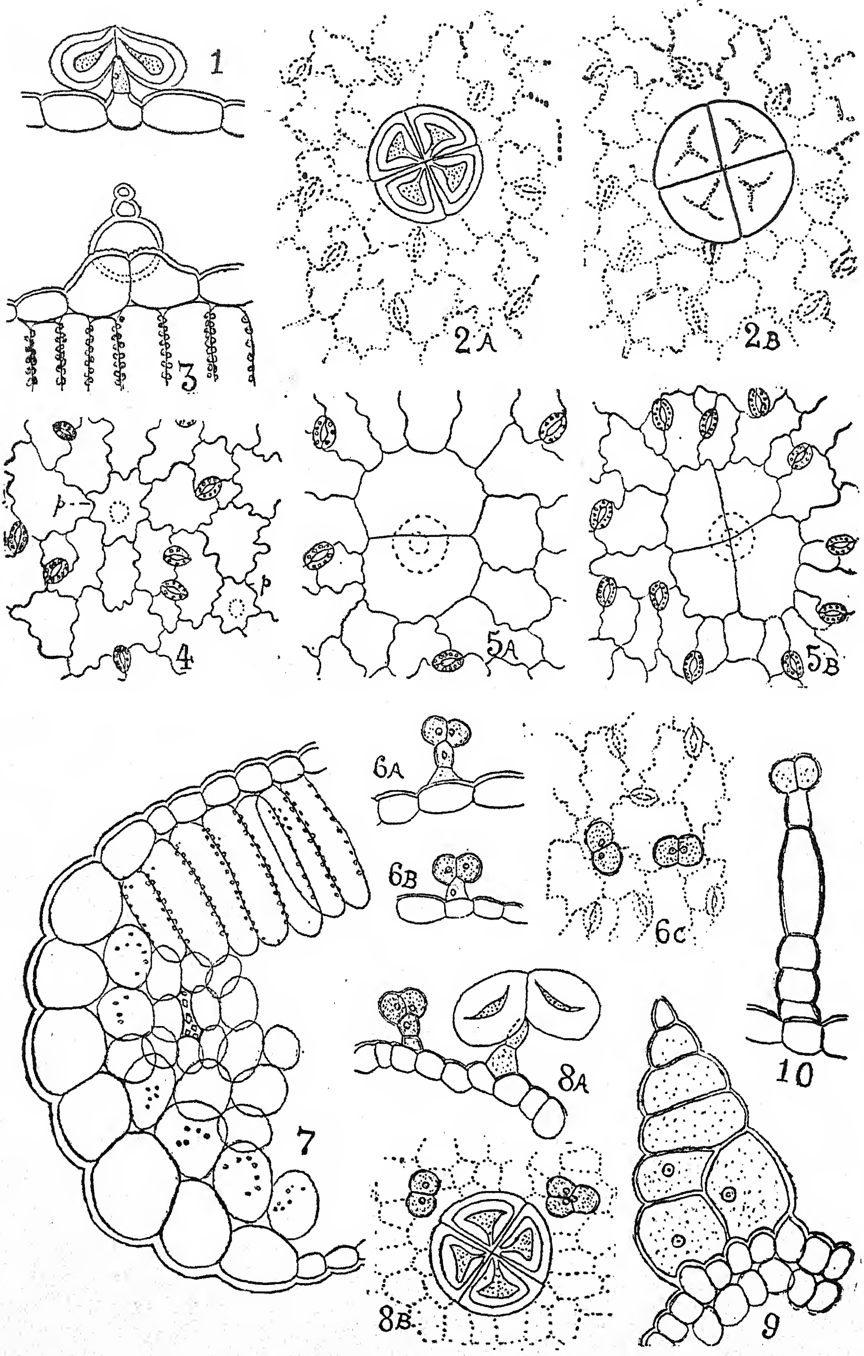
D. P. MULLAN

St. Xavier's College, Bombay

Received for publication on 12th January, 1936

Pedalium murex Linn. is a common inhabitant of the sandy shores of India and Ceylon. Parts of the stem, leaves and fruits, when wetted, are known to exude great quantities of mucilage which is much valued in indigenous medicine. The mucilage is secreted by certain glands, the possession of which is regarded by Oliver (1888) and others as "a decidedly Pedaliaceous character". Oliver (1888) was the first to describe the mucilage-hairs in the genus *Trapella*, a Chinese water plant, and Solereder (1908) and others have done the same about *Pretrea*, a European genus of Pedaliaceae, etc. Apart from passing references by Cooke (1908) and other floristic works, to the presence of mucilage-glands, the available literature does not describe the structure of the glands of the tropical *Pedalium murex* Linn.

In the plant under consideration, the mucilage-glands are especially to be found in great numbers on the under surface of the foliage leaves, where they appear as crystalline bodies, giving the parts bearing them a somewhat frosted appearance. The glands are peltate, with a large head, having a diameter of 0·09 mm. The head is divided crosswise into four more or less clear cells and is attached to a short unicellular stalk (Figs. 1, 2). Under dry conditions, the head cells are invested by a delicate cuticle, within which are the internal layers of the walls immediately surrounding the protoplast of each cell (Fig. 2 A). When wetted, the inner layers of the walls swell considerably and press upon the delicate cuticle, while the cell cavity of each head-cell gets much reduced or almost obliterated (Fig. 2 B). On the lower epidermis, such mucilage-secreting glands are about 100 per sq. mm., while on the upper surface of the leaf, they are scarce. A few similar glands, but having longer uniseriate stalks, of 2-3 cells each, occur here and there, especially along the veins (Fig. 3) or at the margin of the leaf lamina. The unicellular pedicels of the glands are seated on a single ordinary epidermal cell (Fig. 4), while the basal cell of the multi-cellular stalks are inserted in



Figs. 1—10. *Pedalium murex.*

Fig. 1: A mucilage-gland from the lower surface of the leaf; Fig. 2: Top view of mucilage-gland. *A*, under dry condition; *B*, under water; Fig. 3: T. S. leaf, showing a uniseriate stalk of a gland; Fig. 4: Lower epidermis of leaf: *p*, cells bearing the unicellular stalks or glands; Fig. 5: Epidermal cells, bearing uniseriate stalks, on upper (*A*) and lower (*B*) surfaces; Fig. 6: Absorbing-hairs on the leaf: *A*, on upper; *B*, on lower surface; *C*, top view

sockets formed by four or several, enlarged, epidermal cells (Fig. 5). The possession of mucilage-glands on one or both surfaces of the leaves, is a characteristic of many xerophytes. As to the rôle of mucilage secretion in xerophytes, Warming (1909), Haberlandt (1928) and others incline to the opinion that it affords protection against excessive transpiration and helps to retard desiccation.

Apart from the more prominent mucilage-glands, the leaves of *Pedalium murex* also possess other very small capitate hairs. Each of the latter consists of a short stalk, composed of 1-2 cells, and a small head divided by 2, or at times by 3, vertical walls (Fig. 6). The head cells of these hairs have thin walls and abundant protoplasmic contents which appear bright yellow in fresh material. The stalk-cells as well as the head-cells show prominent nuclei. On the upper surface of the leaf blade these hairs are mostly confined to the grooves over the veins, while on the lower epidermis they are also scattered among the large mucilage-glands. The hairs placed along the veins have, as a rule, uniseriate stalks, consisting of 2, or at times 3, cells (Fig. 6A); while those scattered among the mucilage-glands, on the lower surface of the leaf, have comparatively shorter unicellular stalks (Fig. 6B). Their position along the veins and among the mucilage-glands, as well as the fact that coloured solutions penetrate very rapidly into the cavities of the hairs suggest that these small hairs are of the nature of water-absorbing organs.

The leaf is bifacial. Stomata occur on both the surfaces, being about 200 per sq. mm. on the upper and about 250 on the lower epidermis. A peculiarity of the lamina is that the epidermal cells become greatly distended towards the margin of the leaf (Fig. 7). The ordinary epidermal cells are 0·02 mm. deep, while the cells at the margin attain a depth of 0·06 mm. The mucilage-glands as well as the absorbing-hairs occur on the margin. The enlarged marginal cells are all clear and evidently act as water reservoirs. The possession of enlarged epidermal cells, acting as an aqueous tissue, is a characteristic of several other psammophilous halophytes (Mullan, 1931).

The mucilage-glands and the absorbing-hairs are also to be found in great numbers on the young parts of stem and branches and on fresh fruits (Fig. 8). On mature stems the heads of the glands and hairs fall off, while their pedicels persist. The mucilage-glands of the stem resemble those of the leaf but have uniseriate stalks, each composed, as a rule, of 2 cells. The glands confined to the four corners of the somewhat quadrangular apical region of the stem, have longer stalks which become multiseriate towards the base (Fig. 9). The absorbing-hairs on the young stem are similar to those on the leaf (Fig. 8), but, on older parts, they have longer, uniseriate stalks of 5-6 cells each (Fig. 10).

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of *B;* Fig. 7: T. S. leaf, showing the distended cells towards the margin; Fig. 8: Mucilage-glands and absorbing-hairs on the stem. *A,* in T. S.; *B,* top view; Fig. 9: A multiseriate stalk of a gland on a young stem; Fig. 10: An absorbing-hair on a mature stem.

All figures have been drawn to an initial magnification of $\times$ 240 and have been reduced to one-third in reproduction.

Summary

The structure of the mucilage secreting glands, occurring on the leaves, young stems and fruits, is described.

The mucilage-glands are accompanied by other hairs which, from their structure and position, may be regarded as of the nature of water-absorbing organs.

The epidermal cells towards the margin of the leaf get considerably distended and seem to serve as water reservoirs.

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Some recent contributions to our knowledge of Heterothallism in Fungi

By J. H. Mitter, ph.d. (Lond.)

Professor of Botany, University of Allahabad

In 1904 Blakeslee discovered that in certain species of *Mucor* zygospores were produced only when two separate mycelia met. Such species he called "Heterothallic" in contrast to the "Homothallic" ones where zygospores were produced without the requirement of a separate complementary strain. Although he designated the two kinds of mycelia as + and —, he associated the idea of sex with heterothallism as he found only two complementary strains in the group. For some time knowledge of this phenomenon was confined to the Mucorales only. In 1917-18 Mlle. Bensaude and Kniep both independently discovered heterothallism in the Basidiomycetes. Their researches revealed the presence of more than two complementary strains. This, as well as the fact that sex organs are entirely lacking in this group, has led many botanists to dissociate the idea of sex with heterothallism. Following Dodge, heterothallism can be defined as the condition where "monosporous mycelia produce perfect stages only when mated with their reciprocal haplonts". Within the last fifteen years our knowledge of the heterothallism and genetics of the Fungi has advanced with such rapid strides that at the present time this phenomenon is known to exist in at least some species of all the main groups of Fungi. It is the object of the present paper to summarize briefly the more important works done in the various groups in this line.

In the Myxomycetes, which were excluded from the Fungi by DeBary but have been included by many authors in their books on Fungi, Skupienski found that in *Didymium difforme* the plasmodium on fruiting gave rise to spores which were unisexual and produced unisexual myxamoebae that fused only with the myxamoebae of the opposite sex to give rise to a young plasmodium. In the Archimycetes some dioecious forms are known where two separate thalli function as the male and female gametangia, the female being slightly larger than the male. As examples one may cite *Lagenidium Zygorhizidium, Ancylistes closterii* and *Olpidium trifolii.*

Coming to the Phycomycetes proper, we find that in the Oomycetes dioecism was reported in some species of the Saprolegniales by Leitgeb and others but without adequate experimental evidence.

In 1926 Couch first experimentally demonstrated heterothallism (dioecism) in *Dictyuchus*. He found that certain strains when grown separately, invariably remained sexually sterile, but when mated, the male strain produced antheridia and the female oogonia at the points of contact. He also made interspecific crosses between the different strains of *Dictyuchus monosporus, D. magnusii, D. carpophorus* and *D. sterile* and found that the progeny obliterated the specific boundaries. He found a parthenogenetic strain without antheridia and crossed it with a male strain when the antheridia of the latter applied themselves on the oogonia of the parthenogenetic strain. Again, when crossed with a female strain, oogonia were formed both on the female as well as in the parthenogenetic strain but the latter developed its latent faculty of producing antheridia which applied themselves to the oogonia of the female strain and eggs were produced. Couch also made the interesting observation that parts of the germinating mycelium may be male, parts female and parts may be mixed, showing that partial segregation of sex may take place early in the egg-germination. In the other genera of the Saprolegniales heterothallism is not yet known with certainty except in *Achlya bisexualis* reported by Coker and in *Sapromyces reinschii* of the Leptomitaceae reported by Sparrow.

In the Peronosporales, Leonian found that out of his 85 strains of *Phytophthora omnivora* 48 were always heterothallic and the rest were inconstant in their behaviour, being periodically heterothallic and homothallic. Even the heterothallic forms lost their power to produce oogonia in mixed cultures in about 5 generations. An interesting observation was made by Gadd in 1924. *P. Faberi* growing on Cacao and on rubber, separately produced no oospores but when the strains from these two different hosts were mated, abundant oospores resulted. In India Narasimhan in 1930 found that *P. arecae* on *Areca* and *Loranthus* were male strains producing only antheridia while the strain on *Santalum* was female, producing only oogonia. The strains of *P. parasitica* and *P. meadii* in his collection were only female. These observations have given rise to an interesting hypothesis concerning the rarity of oospores in nature which is explained by the possibility of the two sexual strains becoming isolated on the different host plants in nature. The two host plants may grow in sufficiently close proximity to allow for occasional transfer of zoospores of one strain to the other, resulting in the infrequent oospores.

In *Peronospora parasitica* De Bruyn found that out of 11 strains 8 could be divided into two groups which behaved unisexually, forming oospores only on contact with a strain of the opposite group. One strain was potentially bisexual, reacting with either group, and the rest were homothallic.

In the Zygomycetes the classical observations of Blakeslee have been greatly extended both in his laboratory and elsewhere. It

has been found that though the plants are strictly dimorphic, the sexual differences may show varying degrees of intensity. A strain that is very strongly male will conjugate with strains with all degrees of femaleness but a weakly male strain will not conjugate with one weakly female and *vice versa*. The various attempts at intergeneric and interspecific crosses have mostly resulted in imperfect zygospores. The imperfect hybridizations between the homothallic species and the two strains of the heterothallic ones revealed the presence of two strains of the former — (a) those with a "minus" sexual tendency showing a strong reaction with the "plus" races and weak or no reaction with the 'minus' ones,—examples *Absidia spinosa, Zygorhynchus moelleri,* etc., and (b) those with a 'plus' tendency like *Zygorhynchus heterogamous*. Satina and Blakeslee have shown that plus and minus strains possess quantitative bio-chemical differences. They have obtained a difference between the two sexes in a reaction analogous to the Manilov reaction, in which the female strains showed a greater capacity to reduce N/100 $KMnO_4$ solution. Schopfer found in *Mucor hiemalis* a difference between the + and the — strains in their reaction to toxic substances and in their growth on certain natural media. The + and the — gametangia also showed a difference in their carotin content and a strain of bacteria was found which would attack the + but not the — strain. Schopfer regards these bio-chemical differences to be secondary sexual characters.

Differentiation of the sexes occurs in *Mucor mucedo* in some nuclear division within the zygospore prior to its germination so that the sporangium formed from it contains spores of one sex only. In *Phycomyces nitens* the germ sporangium has spores of both sexes showing that sex-segregation occurs in the sporangium. With a delicate technique "grafting" was accomplished by Burgeff in *Phycomyces nitens* between a + and a — mycelium. The mycelial outgrowths from this operation formed sporangia which contained + spores with nuclei coming directly from the + mycelium, — spores with nuclei from the — mycelium and also neutral spores containing nuclei from both + and — mycelia, the mycelia from the last type of spores forming abortive or imperfect zygospores with either of the two sexes. Burgeff crossed some mutant forms of *Phycomyces blakesleeanus* with the parent and found the forms "pilobolides", "arbusculus' and "pallens" to be recessive to the parent but the form "mucorides" was dominant. In a cross between *P. nitens* and *P. blakesleeanus* the latter was found to be recessive. In the Choanephoraceae Weber and Couch have reported heterothallism in *Blakeslea trispora* and *Choanephora conjuncta* respectively. In *Cunninghamella bertholletiae* Burger could not find any strict sexual dimorphism as seen in the Mucoraceae. Difference of sex was quantitative rather than qualitative and union occurred whenever compatible gametes were present. If one of the strains be

designated as + and all others which reacted with it as —, then there were strains which conjugated with both + and — mycelia.

Lastly there is an interesting hypothesis by Burgeff according to whom the attempts at hybridization have led to parasitism of *Parasitella simplex* on *Absidia glauca.* He found the + strain of *P. simplex* parasitized only the — strain of *A. glauca* and the + mycelium of *A. glauca* was parasitized only by the — strain of *P. simplex.*

Amongst the lower Ascomycetes heterothallism has been reported in *Penicillium luteum* by Derx who found that single spore cultures formed sterile haploid ascocarps, fertile fruit bodies being produced only by the union of the opposite sexual strains. The rarity of ascocarps in this genus may be due, according to him, to the modern methods of purification, *i.e.,* by single spore cultures and it is suggested that strains from different sources should be crossed. Blochwitz, however, thinks that Derx's results are due perhaps to contamination with *Aspergillus glaucus.*

Wieben demonstrated that in *Taphrina epiphylla* and *T. Klebahni* the ascospores or the spores budded off from them are unisexual and uninucleate. Active infection of the host was possible only when the germ-tubes of two ascospores of the opposite sexual tendencies fused and gave rise to a diploid mycelium with each cell containing a dicaryon. In *T. deformans,* however, Fitzpatric observed that though the mycelium carried dicaryons, the germ-tube from a single spore could produce infection. Its nucleus divided into two and thenceforth the two nuclei divided conjugately.

Some of the Ascomycetes parasitic on insects are dioecious and the motility of their hosts probably overcomes the difficulties of fertilization. In *Pericystis apis* and *P. alvei* Claussen observed that the male plants were larger than the female. In Laboulbeniales there are also dioecious forms such as *Amorphomyces falagriae* where there are paired spores of different sizes, the smaller giving rise to the male and the bigger to the larger female.

In the Discomycetes Dodge reported heterothallism in *Ascobolus magnificus* which is structurally monoecious bearing both antheridia and oogonia, but functionally dioecious. The antheridia of strain A will fertilize only the oogonia of strain B and the antheridia of strain B will unite only with oogonia of strain A. The fungus was, therefore, self-sterile. A similar situation has been observed by Betts in *A. carbonarius. A. strobilinus,* however, is homothallic. In *A. stercorarius* Dowding observed that the oidia produced by this fungus are unisexual and are transported by mites or flies and possibly wind, to the mycelium of the opposite sex where apothecia are produced. A similar function for the oidia or microconidia has been discovered in *Sclerotinia gladioli* by Drayton. As early as 1861 Tulasne described them as spermatia and prophesised that "sometime or other it would be demonstrated that there

resided in them a certain force or nature like that of pollen". Drayton found that the mycelium produced microconidia like *Botrytis,* sclerotia like *Sclerotium* and receptive hyphae. Apothecia were produced only when microconidia from a compatible strain were placed on the receptive hyphae. Fruit bodies did not develop in pairings of vegetative hyphae or if microconidia were placed on the vegetative hyphae. The fungus was thus found to be self-sterile but it is inter-fertile as the strains on *Crocus* and *Gladiolus* were found to be compatible strains and could fertilize mutually. *Sclerotinia sclerotiorum* and *S. Ricini,* however, formed apothecia in monoascosporic cultures and were probably self-fertile. The condition in *Ascobolus* and *Sclerotinia,* therefore, is not sex-heterothallism or the condition of maleness and femaleness of the two strains such as occur in the Mucorales, but physiological heterothallism based on one sterility or compatibility factor which segregates in a 1 : 1 ratio in ascospore formation. It is comparable to the self sterility to their own pollen in such flowering plants as *Primula* where there are also only two interfertile but intra-sterile types. The condition in *Humaria granulata* is interesting. It is an apogamous form and the oogonia fuse with hyphae only from a complementary strain. Gwynne-Vaughan who worked out this species, holds that this is not sex-heterothallism as the male organs are entirely lacking. She has, therefore, advanced the theory of "Nutritive heterothallism" on the assumption of a hereditary ability of the different strains to extract different nutritive substances. Suppose one of the mycelia can extract only food substance A from the substratum and the complementary mycelium can absorb only the food substance B present in the same substratum. When both the strains are present the substances A as well as B, both of which are necessary for ascocarp formation, will be absorbed and fruit-bodies will result. This theory has been tested by Gregor in the pyrenomycete *Ceratostomella paradoxa* by using various substances to induce the formation of fruit bodies in single-spore cultures but negative results were obtained and Gwynne-Vaughan and Williamson themselves stated that they have not yet been able to justify the term. Among the Hysteriales in *Lophodermium pinastri,* the cause of Pine blight, Jones observed that apothecia arise only from inter-mingling of mycelia after multiple infection.

In the Pyrenomycetes heterothallism is known in a number of forms but the work of Dodge and others on *Neurospora* has thrown a flood of light on the genetics and heterothallism of the Ascomycetes. *N. sitophila, N. crassa,* and *N. tetrasperma* are heterothallic but *N. erythraea* is homothallic. Moreau believes that actual contact between the complementary strains is not necessary for the production of perithecia but these are due to the diffusion of certain substances analogous to hormones. In a U tube with a constricted middle and the two strains placed at the two ends, perithecia appeared only on one end, and the narrow part when

incubated gave rise to no mycelial growth. Dodge and Aronescu, on the other hand, found that perithecia arose only by contact of the two strains even in the middle of the U tube if sufficient oxygen is present. In *N. sitophila* Wilcox isolated all the 8 ascospores of a row and found that either the + and — spores alternated in pairs or 4 spores of one sex lay between the two terminal pairs of the opposite sex. They never alternated singly, thus showing that segregation of sex took place at the 2nd division in the ascus. Lindegreen found that in *N. crassa* sex-segregation took place more frequently in the first than in the 2nd division so that more often the 4 consecutive spores were of one sex. *N. sitophila* formed orange coloured monilioid conidia but one of its mutant forms produced albinistic conidia of *Botrytis* or *Sclerotinia* type. On crossing the albinistic strain with the coloured one, the factors for sex and colour behaved as independent unit characters and segregated separately. Of the 8 ascospores, four gave rise to albinistic strains of which two were + and two — and the other four gave rise to two + and two — normal coloured strains. Based on their position in the ascus, it was found that both the characters may segregate at the first division or both may segregate at the second or one at the first and another at the second division in the ascus. The progeny of a cross between albinistic *N. sitophila* and normal *N. crassa* consisted mostly of *N. crassa* type, a few were albinistic and some showed combination of characters being albinistic intermediates. *N. tetrasperma* normally has 4 spores in the ascus each of which is binucleate and bi-sexual, giving rise to perithecia. Often, however, the number of spores is increased to 5 to 6 by the division of one or two of the larger binucleate spores into two smaller uninucleate ones which are then unisexual and require fusion with a complementary strain to produce perithecia. It was found that treatment with X-ray affected the nuclei of one sex only in a binucleate bisexual ascospore so that they behaved as unisexual spores. Some strains were found with aborted indurated asci. The lethal for ascus abortion was heritable being carried in the nucleus and each binucleate spore had one normal and one lethal nucleus. The F_1 hybrid of this and the normal strain showed some aborted asci. The small uninucleate ascospores that happened to get the lethal nucleus died soon after germination while others without it produced normal mycelium. In a cross between *N. sitophila* and *N. tetrasperma* the progeny resembled the former more closely but there was much spore abortion. A condition similar to *N. tetrasperma* has been observed in *Pleurage anserina* by Dowding and Ames. The ascus has three kinds of spores, (a) normally four binucleate, bisexual spores, (b) two giant 4-nucleate bisexual spores and (c) occasionally a few dwarf uninucleate unisexual spores. The mycelia from uninucleate spores were self-sterile but reciprocally fertile and those from normal and giant spores self-fertile but isolations from young hyphal tips were self-sterile. The

mycelium from normal ascospores is, therefore, considered to comprise of two hermaphroditic cultures growing intermingled as one, each giving rise to male and female organs, which are self-sterile but reciprocally fertile. It is therefore held to be no longer justifiable to conclude that a culture derived from a single spore is simply bisexual and self-fertile because it produces fruiting bodies when grown alone. In *Diaporthe perniciosa,* Cayley found three forms of heterothallism—(1) true sex-heterothallism, (2) heterothallism based on one or two self-sterility factors, these forms showing intra-perithecial aversion and (3) heterothallism based on inter-racial sterility but self-fertility factors—these showed inter-racial aversion, *i.e.,* a sterility between biologic races. This negative sterility factor causing aversion is segregated independently of sex. Edgerton found that in *Glomerella cingulata* the two complementary strains, which had formerly been regarded as different species, each separately gives rise to a few perithecia with small or immature asci but at their point of contact, abundant perithecia with large well-developed asci are produced. Shear and Wood think this to be a case of hybridization but Edgerton does not regard it to be so. *Ceratostomella pluriannulata, C. ulmi* and *C. paradoxa* are heterothallic forms, the last in single spore cultures giving rise only to the conidial form *Thielaviopsis paradoxa.*

More than 60% of the Basidiomycetes are supposed to be heterothallic. In Ustilaginales, Kniep showed that in *Ustilago violacea* and other forms, the sporidia belonged to two groups which fused with each other. Dickinson observed that single sporidial cultures of *U. levis* (*U. Kolleri*) and *U. hordei* could not infect the host which was only possible after fusion with sporidia of the opposite sex. He also found that the four spores from the same basidium showed differences in vegetative characters such as colour of the mycelium, form of the colony, etc., and these characters together with sex segregate independently either at the 1st or at the 2nd division in the promycelium. Hüttig has shown that temperature has a considerable effect on the proportion of segregation at the two divisions in *U. avenae.* In *U. Zeae* Hanna found that monosporidial cultures could infect tender parts of the host but chlamydospores were not formed. He also showed that there were 4 strains with two alleomorphic pair of genes-AaBb. If disjunction occurs in the 1st division then sporidia of one promycelium will be of 2 kinds, either AB and ab or aB and Ab, but if disjunction occurs at the 2nd division, then all the four kinds of sporidia will be borne on the same mycelium. The same condition was found in *Sorosporium reilianum* and Bauch also obtained similar results with *U. longissima.* Hanna crossed *U. avenae* which forms loose smut with echinulate spores and *U. levis* forming covered smut with smooth spores and found that the appearance of the heads produced by the hybrids was variable, being more of the loose type and that echinulate was dominant over smooth.

Crossing *Tilletia laevis* with *T. tritici* he found *T. laevis* to be dominant and Rodenhiser found *Sphacelotheca cruenta* to be dominant over *S. sorghi*.

In 1927 Craigie discovered heterothallism in the Rusts and found that monosporidial mycelia of *Puccinia graminis* and *P. helianthi* produced both spermogonia and sterile aecial fundaments, but if spermatia only from the complementary strain were placed on it, fertile aecia resulted. The spermatia, which were long held to be of doubtful function, bring about the diplodization of the haploid monosporidial mycelium in two ways—(1) the spermatial hyphae grow down into the aecial beds and fuse there with the basal cells forming the "two-legged" cells which cut off aecidiospores as observed by Blackman and Christman or (2) spermatia fuse with the receptive hyphae which come out of the stomata, or between the epidermal cells or from the ostiole of the spermagonium, and the spermatial nuclei pass through the mycelium diplodizing every cell, the "two-legged" cells originating by the downward proliferation of the basal cells. The first process according to Hanna takes 48 hours in *P. graminis* and Allen observed that by the second process at least 60% of the cells in *P. sorghi* become diploid only 24 hours after spermatization. According to Brown diplodization can be accomplished even by a mycelium carrying a dicaryon like that forming the uredinia. Newton and Johnson found that a hybrid resembles, in pathogenic characters, the aecial parent more than the spermatial parent. This is explained as cytoplasmic inheritance as the aecial parent contributes the major part of the protoplasm of the hybrid. Craigie, however, observed that the pathogenic behaviour of the hybrid, in *P. graminis* to be intermediate between the parental forms. A cross between forms with orange and greyish-brown uredinia gave rise to hybrid with normal red pustules which in the F_2 generation formed 4 types of uredinia — normal red, orange, greyish-brown and almost colourless. That hybridization occurs in nature is shown by the dissociation, in pure cultures, of the heterozygous strains into its constituent forms and this probably explains the reported break down in the resistance of the host. Heterothallism has been reported in a number of genera of the Uredinales such as *Puccinia, Uromyces, Gymnosporangium, Melampsora, Endophyllum,* etc., and an investigation into the other genera will certainly prove fruitful.

In some species of the Autobasidiomycetes heterothalism has been intensively studied. Kniep found in *Schizophyllum commune* that the mycelium from a single spore can give rise to the fruit bodies but spores formed from them are of the same sex and clamp connections are entirely absent though the hyphae exhibit anastomoses. Thus it was found that the clamp-connections aer not solely nutritive as was thought before. He also found that there are four different strains whose genetic constitution is control-

led by two pairs of allelomorphic characters AaBb so that the four kinds are AB, Ab, aB and ab. Union occurs between mycelia without a common factor, for example, between AB and ab but not between AB and Ab. The constitution of the basidiospores in a basidium will be determined by the division in which segregation of these two factors occurs, in the same manner as found by Hanna in *Ustilago Zeae*. On this basis Kniep held that segregation took place in the 1st division in *Aleurodiscus polygonius* as he found only two types of basidiospores in a basidium, but according to Hanna it takes place in the second division in *Coprinus lagopus* as all the four kinds of spores are present in a basidium. Many species of *Hypholoma, Collybia velutipes, Trametes suaveolens,* etc., are known to be quadripolar but not all the forms are such. There are many bipolar species having only two forms controlled by a single pair of allelomorphic characters Aa, such as *Coprinus rostrupianus, C. radians, Fomes roseus, Panaeolus complanatus,* etc. Bose found *Polyporus ostreiformis* and *Polystictus hirsutus* to be strictly bisexual and that aversion showed by them is not related to sex. *Polyporus borealis,* however is tetrapolar. There are many homothallic forms also such as *Coprinus sterquilinus, C. ephemeroides, Polyporus resinosus,* etc.

Sass observed in *Coprinus ephemerus* and other forms that in addition to the 4-spored basidia, some of the basidia bore only two spores which were binucleate and gave rise to homothallic mycelium but the hyphal tips were uninucleate and fused with uninucleate hyphae carrying the nucleus of the opposite sex. The condition was similar to that described by Ames in *Pleurage anserina.*

Oort was able to induce "illegitimate unions" between two mycelia of *C. fimetarius* which were genetically alike for one factor such as between AB and Ab, and found that the clamp connections were abnormal and the basidia were 2-spored.

Vandendreis observed that 27 cultures of *C. radians* after some time passed spontaneously from the haploid to the diploid condition, showing clamp connections. He holds the view that all the species are "hetero-homothallic", being at the beginning heterothallic. The homothallic forms change from haploid to diploid very soon but in the species regarded as heterothallic this change takes a long time if allowed to occur spontaneously. The work of Buller shows that in addition to the mating of mycelia, diplodization may be brought about by the oidia produced by the haploid mycelia and transported to the mycelium of the opposite sex by mites, flies and wind. The nucleus of a single oidium may diplodize the whole mycelium as, though united in a dicaryon, it may divide independently and the daughter nucleus may go to the next cell by forming a clamp. Buller found that the oidial nucleus, in this manner, travelled at the rate of about 1·5 mm. per hour.

Crossing the strains from distant geographical places Vandendries noted inter-racial sterility in *C. micaceus* but complete inter-racial fertility was observed by Hanna in *C. lagopus* and by Kniep in *Schizophyllum commune*. The mycelia from each of the six fruit bodies from different places studied in *C. lagopus* separated into 4 groups, as usual, but all of them were fertile with all the strains derived from other fruit bodies. There were, therefore, not 4 but 24 distinct groups.

Such conditions in these forms have led people to theorize about their nature. It has been assumed that there are only two sexes and the interactions between them according to Kniep, are controlled by positive sex factors which may undergo frequent mutations giving rise to new sexual strains. Thus factors AaBb may mutate to give rise to A′a′ B′b′ showing complete fertility with the parent. To obviate the necessity of the assumption of the infinite number of allelomorphs possible according to Kniep's theory, Brunswik suggested the simpler conception of one or more negative sterility factors. All the strains that do not possess such factors will unite with each other. Cayley has put a corollary to the last hypothesis by suggesting that the mycelia are potentially bisexual but do not fruit due to the presence of self-sterility factors. Hartmann has advanced the theory of relative sexuality according to which they are potentially bisexual but behave unisexually, the sex being determined by internal factors such as the activity of the protoplasm and not by chromosomes as postulated by Kniep and Brunswik. In the presence of a strain with similar but stronger sexual tendency it will behave as if of opposite sex.

From what has been said in the preceding pages it is clear that heterothallism exists from the lowest to the highest groups of Fungi. The recent genetical studies have revealed results that can to some extent parallel those obtained in the flowering plants. It has been seen that heterothallism can be present even in those forms which bear both the male and the female organs. Gwynne-Vaughan thinks that this condition arose in connection with their invasion of land. It is surmised that "in a changing environment the limited variability associated with constant self-fertilization became harmful and since an evolutionary step can apparently never be retraced, survival lay with those forms which by a fresh device, ensured the combination of characters from different individuals". The study of heterothallism has explained the sterility as also the production of abundant fruit bodies at one time and their scarcity at another of several forms and, where environment is not the controlling factor in the production of perfect stages, it has given us the key to handle the problem in many a species of Fungi.

I wish to acknowledge my indebtedness to my colleague Mr. Anil Mitra for his very great help in the preparation of this paper.

PLANT COLONIZATION ON TWO NEW TROPICAL ISLANDS *

BY

EILEEN WHITEHEAD ERLANSON, PH.D. (Mich.), D.SC. (London)

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Cochin Harbour Reclaimed Land

Until five years ago there was no port on the west coast of India, south of Bombay, where ocean-going liners and big freighters might put into harbour. To obviate this drawback to shipping, the fine, large but shallow lagoon-like harbour of Cochin has now been dredged under the joint auspices of the Governments of British India, Travancore State and Cochin State.

Millions of cubic feet of alluvial soil, ooze, sand and oyster shells have been pumped off the bottom of the harbour in order to provide a suitable channel and berths for modern ships. All this waste material has been utilized to form two islands, known as the Reclamations, inside the harbour (Text-fig. 1). Since the population of the shores contiguous to the harbour is very dense, the Reclamations will supply needed ground for steamer berths, docks and railway sidings.

The larger reclamation has been named Willingdon Island. It lies close to a sandy island called Venduruthi, and is therefore sometimes spoken of as the Venduruthi Reclamation. It is referred to as Willingdon Island in this paper. To make such an island a sea-wall, about 7 feet high of loose granite stones is first built to enclose the area to be reclaimed; then the sludge is pumped in. The dredger sucks and grinds up shells, mud and sand, together with a lot of sea water. For some time the new soil is a semi-liquid saline mass containing a few dead fish and eels, which are devoured by crows and kites. The dredging operations in Cochin Harbour are little hampered by waves, except during the monsoon. The harbour is actually a huge lagoon with one narrow opening into the Arabian sea between Vypeen and British Cochin. The rise and fall of the tide is only about two and a half feet. The north-west end of Willingdon Island was reclaimed first; dredging began in 1926 and by 1932 there were 250 acres of reclamation completed. The southern half of the island was

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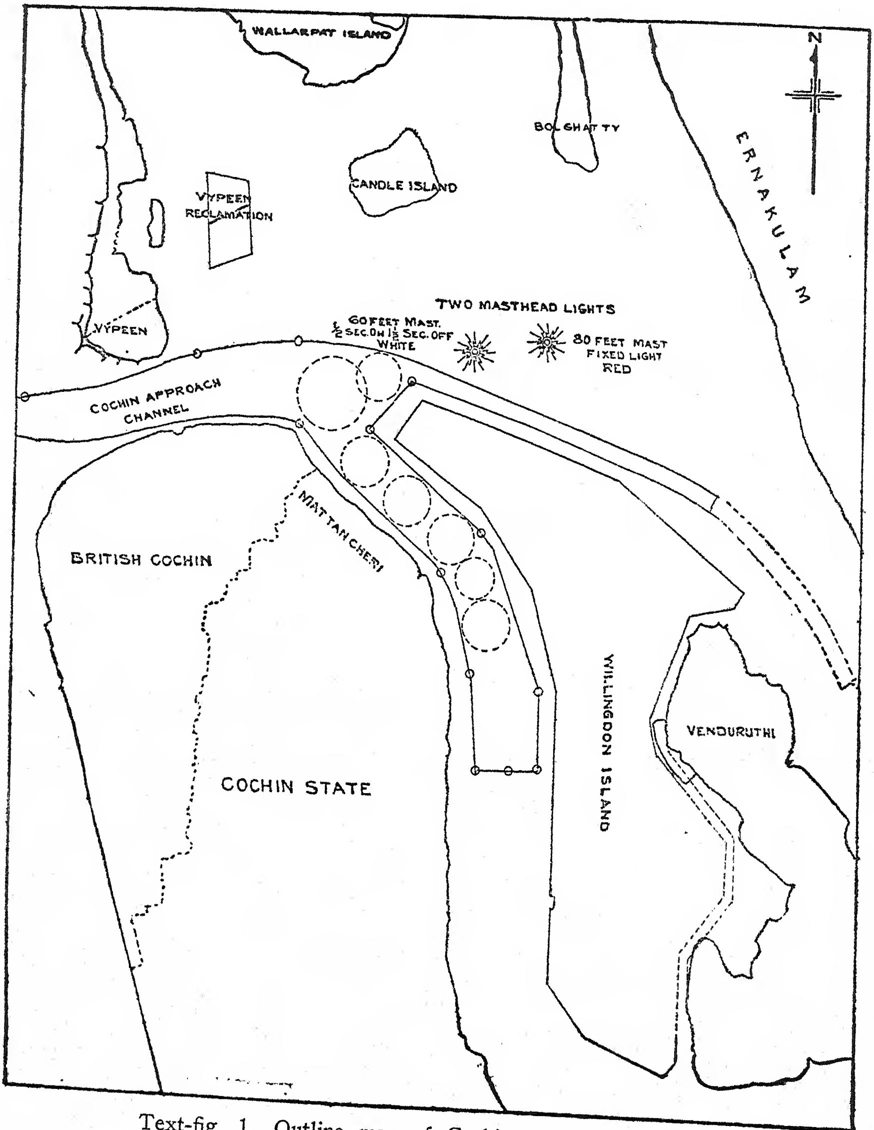
* Paper from the Department of Botany of the University of Michigan, U.S.A.

constructed in 1932 and 1933, although some dredgings have been placed there since. The total length is two and a half miles and the average width about 800 yards.



Text-fig. 1. Outline map of Cochin Harbour in 1935.

The other reclamation is a small rectangular island, the southern part of which was completed in 1932 and is about 1,000 feet square. Dredgings were still being placed along the northern

shore in 1935, and its size will eventually be almost doubled. This island is just inside the northern arm of the harbour, a wide natural sandbar known as Vypeen; the island is therefore called Vypeen Reclamation.

Aspect of the Vegetation

In 1935 the north-west end of Willingdon Island was clothed with a luxuriant growth of plants, a tangle of grasses, giant sedges, shrubs and delicate twining plants, together with many small flowering plants and ruderals, with here and there a tree sapling shooting up and even a few good-sized trees. The general aspect of the vegetation on the reclamation is not tropical, but temperate (Plate XVIII, Fig. 1); it recalls the glaciated plains of southern Michigan and northern Indiana with their luxuriant growth of grasses, perennial herbs and shrubs and scattered deciduous trees and contrasts strongly with the vegetation on the low sandy shores of the harbour and of the Malabar Coast. These shores are covered with hundreds of cocoanut palms crowded together in an intense cultivation on every patch of ground not occupied by towns and villages. Under the palms the soil is bare sand with a few herbaceous weeds which are grazed unsparingly by thin and hungry cattle and goats. Some of the country people grow patches of vegetables beside their mud and palm-leaf huts and protect them with hedges and fences. In the grounds of the larger houses there are many fine trees, both native and introduced, as well as shrubs, ornamental plants and lawns. There are also a few members of the Indo-Malay strand forest formation scattered along the shores of the islands near Cochin Harbour left undisturbed by the teeming population.

Scarcely any of the outstanding species of the neighbouring region are found on the reclamation. Even the characteristic shrubs of the dry scrub jungle of the Malabar coastal plain are not yet established. Because the plant growth appears unusual at first glance, people have come to believe that it consists of plants not found in the district. The popular theory is that these plants have sprung from seeds that had been lying dormant for years on the floor of the harbour, and that these seeds had been brought down year after year by the great Periyar, Bharata and other rivers from high altitudes in the Western Ghats. There is a great river system from the mountains which enters the wide shallow channels, known as "backwaters", which are separated from the sea by sand bars but are connected with Cochin Harbour. This theory is untenable, for I shall be able to show (1) that most of the seeds that arrived at Willingdon Island were not water-borne but air-borne and (2) that all the species present occur in the region of the harbour.

Meteorological Conditions

Cochin Harbour lies in the path of the south-west monsoon and receives an abundant rainfall of 122 inches a year (4), most of

which falls in the six months of May to October. In both June and July over twenty-five inches of rain are usual. Some precipitation occurs each month, and the average number of rainy days in Ernakulam on the east side is 130.

The atmosphere is always warm and humid and the temperature very uniform. The lowest mean humidity is as high as 70 per cent. of saturation, and the highest is 88 per cent. This humidity, together with the heavy rainfall, to a large extent counteract the xerophytic soil conditions of the reclamations; and the heavy rains rapidly wash the sodium chloride from the dredged soil. The average cloudiness is 48 per cent. of the sky expanse. The mean annual maximum temperature for twenty years was 87·4°F., and the mean minimum 75°F.; the annual mean was 81·2°F. Temperatures above 100°F are not obtained on this coast.

The year is divided into three seasons:—the Dry Season in December, January and February; the Hot Season from the end of February until May; the Wet Season which begins in June when the South-west Monsoon breaks. When the monsoon comes the temperature falls to 77°F, the skies are clouded, and heavy frequent showers and squalls occur until mid-September. In October and November the north-west Monsoon brings refreshing, but not heavy, showers.

The prevailing wind is south-westerly from June until November, and is very strong with frequent gales in the first three months of the monsoon. From December until June the winds are less intense, they blow more from the west and north, and there is often a land breeze in the morning and a sea breeze from midday until sunset. It is evident that wind might be an important agent in transporting seeds and fruits in this area.

Edaphic Conditions

Surface soil conditions are varied on Willingdon Island, and this affects the succession of plant colonization. The southern, newest half is nearly all alluvial mud, with some sandy patches. The north-west end also has large patches of fine, moist, alluvial soil, as well as some banks or islands consisting of solid masses of large oyster shells, and some very sandy portions.

Soil analyses of samples taken in January 1935 from three levels in seven pits scattered over the reclamation, are shown in Tables I and II. The high percentage of sodium chloride in samples 1, 5 and 6 represents the amount present in alluvial sludge about a year after it has been exposed to the elements. The percentages in the other samples show the rapidity with which the salt is washed out of the soil by the torrential rains.

In 1935 large areas of the alluvial mud one mile down the reclamation from the north-west end were still quite bare. The surface soil was salt to the taste and a weak deposit of white crystals was visible in places.

On Vypeen Reclamation the soil is mostly coarse sand intermixed with alluvium and the shells of molluscs. The new northern end was still a liquid mass of mud and salt water in 1935.

Biotic Factors

On the extreme north-west end of Willingdon Island four houses for the Harbour Engineers and a small-modern hotel, have been built. They are now occupied and the inhabitants occasionally walk along the footpaths on the island, but they do not disturb the vegetation to any extent. Trees and ornamental shrubs have been planted in the gardens, and some volunteer saplings have been transplanted. Indians sometimes land and cut sedges and grasses for fodder, but there are no grazing animals on the island. Large lizards and several species of birds are abundant, as well as various insects. No snakes have been seen, and the fauna is never much in evidence.

Plant Succession

Dredging operations for reclamation were begun at the north-west end of Willingdon Island. They were continued southwards and the island therefore shows several stages in the succession of plant colonists. The southern end, for the most part, was two years old in 1935 (Text-fig. 2). Some of the central area had been covered in freshly dredged material only a year ago, but most of this part and the north-western end was three years old. Vypeen Reclamation was about three years old.

Much of the soil is still bare or carries only a few scattered plants, excepting for about three-quarters of a mile at the oldest, north-west end, where vegetation is thick and luxuriant. Undoubtedly the greatest bar to plant colonization is the salt which is left in the surface soil after it is dried by the sun.

My first observations were made in April and May 1935, at the end of the Hot Season and just before the monsoon. Even then there were large patches of semi-bare black alluvial soil which were still somewhat moist. The fine soil had packed together and cracked into irregular blocks in the sun.

No blue green algae or diatoms were found at this time, and they play little if any part in the plant colonization here. Treub (9) reported that they were abundant on the bare soils of Krakatau. After the monsoon, in September, many of the flat bare areas of

mud were quite wet and soft, and some colonies of the Blue Green alga, *Microcoleus cthonoplastes* Thuret, were observed together with a few diatoms.

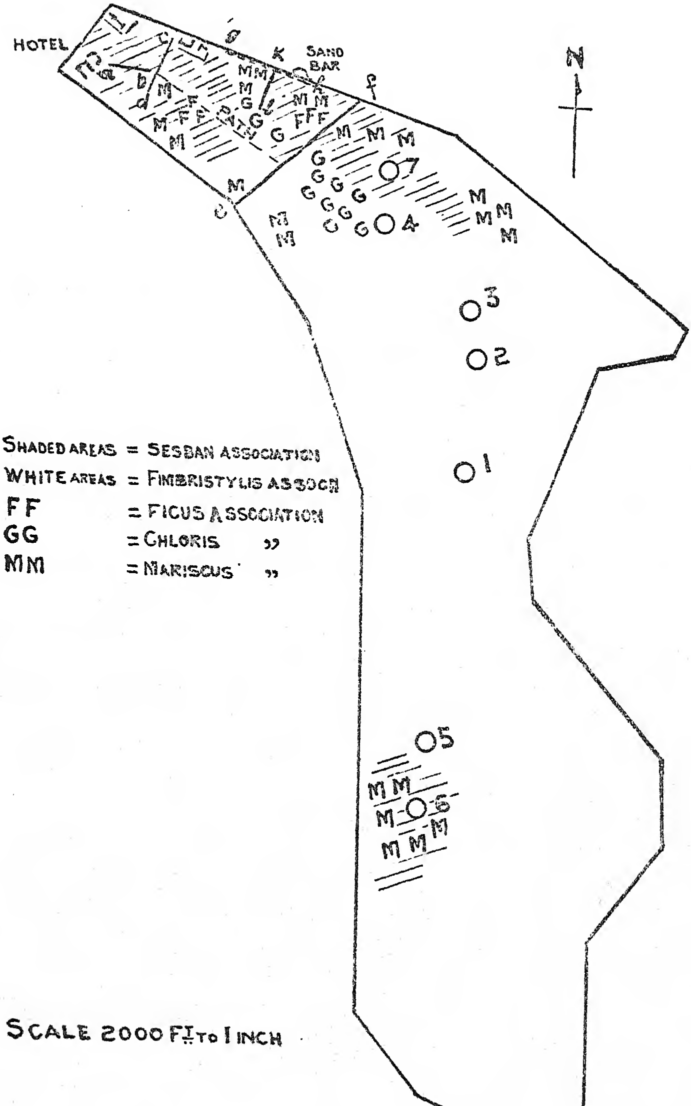


FIG. 2. WILLINGDON ISLAND
NUMBERS SHOW APPROXIMATE POSITION OF SOIL SAMPLE PITS
LETTERS a–b, c–d, e–f, ETC. SHOW POSITION OF TRANSEPTS.

Text-fig. 2. Willingdon Island.

The first colonists on the bare, saline, alluvial mud are the small sedges *Fimbristylis spathacea* Roth. and *F. ferruginea* Vahl. These formed compact cushions on the bare areas on the central and southern parts of Willingdon Island, as well as on Vypeen Reclamation. In the north-east part of Willingdon Island *F. polytrichoides* R. Br. was also found scattered in open formation. *F. spathacea* thrives well and has produced extensive pure stands. *F. ferruginea* holds its own against the next two invaders, and can still be found in the low moist spots among the tangled growth of the north-west end of the island.

Soon after the *Fimbristylis* a big xerophytic and halophytic grass begins to get established and forms dense scattered tufts 2-3 feet high. It has been identified as *Diplachne fusca* Beauv. by C. E. C. Fischer, Esq. In fine black soil, where the salinity is a little less, whole areas have been colonized by a giant sedge *Mariscus pennatus* Don., which also forms thick-set clumps. Stands of this coarse sedge are dense enough to exclude nearly everything else. After the *Fimbristylis* association the *Mariscus* association is the next stage on alluvium. Secondary species found with it are *Passiflora foetida* L., *Fimbristylis ferruginea, Calotropis gigantea* R. Br. and saplings of *Tamarindus indica* L. and *Ficus religiosa* L. (Plate XVIII, Figs. 1 and 4).

Where the soil is a sandy loam, the striking and vigorous *Sesbania aegyptiaca* Pers. replaces the giant sedge and forms the dominant species of a third association of plants. This sturdy annual grows to a height of 7-8 feet and is strongly frutescent with abundant dark green foliage. It forms open thickets in association with *Passiflora foetida, Tridax procumbens* L., *Melothria maderaspatana* Cogn., *Corchorous acutangulus* Lam., several weedy members of the Compositae, some small grasses and a few large bushes of *Calotropis*. In the *Sesbania* association small secondary pure stands are present of *Sesbania procumbens* W. & A., *Sebastiana chamaelea* Muell., *Achyranthes aspera* L., *Mimosa pudica* L. and *Lippia nodiflora* Rich. The latter has formed a dense colony in a moist depression a few yards wide, where it grows 6-8 inches tall; its heads of delicate lilac flowers give the effect of a piece of alpine meadow. *Lippia* also grows short and prostrate on the shell and sand of the central pathway. A single large tree of *Ficus glomerata* Roxb. (Plate XVIII, Fig. 2), 25 feet high, has entered this association, as well as a few saplings of *F. religiosa, Alstonia scholaris* R. Br., *Bombax malabaricum* DC. and *Eriodendron*. A *Casuarina* tree and a few bushes of *Dodonia, Pavonia* and *Sida* are also present.

In the coarse sandy areas, the common grass *Chloris barbata* Sw. takes the dominant rôle. It covers a considerable area in the central part of the island. It is associated with a few large trailing plants of *Luffa aegyptiaca* Mill., *Ipomoea reptans* Poir, and *I. pes-*

caprae Sw. Although the latter is the commonest and most wide-spread member of the Indo-Malay Strand flora it has only gained foothold in two areas on Willingdon Island, close to the hotel and half a mile to the south near the northern shore. Single shoots of this plant measure as much as 30 feet on the island, and lie prostrate on the sand.

On the marl banks where the soil is a porous mass of oyster shells for several feet down, there is a *Ficus* association (Plate XIX, Fig. 2), with many young trees of *Ficus religiosa* some of which are 15 ft. tall. There are also some Banyan trees (*F. bengalensis* L.) and one young tree of *Ficus Tsiela* Roxb. Secondary species are *Passiflora foetida, Cynanchum calliata* Ham., and *Leptadenia reticulata* Wt., all climbing on the young trees. This porous ground should not retain much salt after one monsoon, but it is still very bare with patches of *Passiflora, Chloris, Fimbristylis spathacea, Tridax* and a few other weedy composites. A bush of *Breynia rhamnoides* Muell. and one of *Pajanelia* also grow here.

The above five plant associations are fairly distinct on Willingdon Island, namely: *Fimbristylis, Mariscus, Sesbania, Chloris* and *Ficus*. There are also isolated pure stands of limited area of the following species, chiefly found along the north shore:—

1. *Imperata cylindrica* Beauv. var. *Koenigii* Desv. (Plate XVIII, Fig. 1). A large grass that forms bulky individual clumps in rich muck soil. It is common in swamps along the backwaters.

2. *Arundo Donax* L. A very tall reed-like grass. It is often grown in gardens (Plate XVIII, Fig. 4).

3. A wild bean, probably *Phaseolus adenanthus* G. F. Mey. which was not observed in flower or fruit. It grew very rapidly after the monsoon and spread by shoots 15-20 feet long over the clumps of *Mariscus*.

4. *Calonyction Bona-nox* Boj. (syn. *Ipomoea bona-nox* L.) has become established on a sand-bar below the sea-wall on the northern shore. It has also spread over the island at that point. It is a native of the hills but is commonly grown in gardens for its beautiful night-blooming flowers (Plate XVIII, Fig. 3).

5. *Sphaeranthus indicus* L., a common annual weed in paddy fields, formed open colonies on bare saline mud patches near the north shore wall in August after the monsoon.

6. *Sesbania aculeata* Pers. is found occasionally in the *Sesbania* association. One thicket over 12 feet high was growing in a bare mud area in August and was most striking.

A total of eighty-six species of phanerogams was collected. Many of these are annual weeds, some of which were probably brought in through the agency of man during the construction of the buildings. Among the common ruderals of the region which grow on the reclamation are: various grasses including *Eragrostis tenella* R. & S., and *Dactyloctenium aegyptiacum* Beauv. (an Indian cereal crop plant) ; *Portulaca oleracea* L., *Eclipta alba* Hassk. and other Compositae, some small species of *Euphorbia, Leucas aspera* Spreng. and *Cassia Tora* L. After the monsoon many little dainty plants of the annual *Vandellia crustacea* Benth. appeared along the central pathway, where *Boerhaavia diffusa* L. and *Bourreria hispida* K. Sch. also grow. The species occurring along some measured linear transepts in the northern part of the island were recorded and will be found in Appendix I.

The Vypeen Reclamation

The southern end of this reclamation was over two years old in 1935. The soil is a coarse sandy loam with many broken shells intermixed with it. Most of the ground is still bare and the vegetation is only in the second stage of development corresponding to the *Mariscus* and *Sesbania* associations on Willingdon Island. However the associations are less well-marked here, and all species are less vigorous (Plate XIX, Figs. 1 and 3). All the species found also grow on Willingdon Island (Appendix II). The following are the species which were observed in May 1935:—

Fimbristylis ferruginea
F. spathacea. } Pioneers on open heavy soil.

Mariscus pennatus. A few tall clumps.

Sesbania aegyptiaca—frequent on the west side.

Calotropis gigantea—frequent on the west side—3-5 feet high.

Tamarindus indica—a few saplings on the west—3-4 feet high.

Lippia nodiflora—one colony 4 feet in diameter on sand.

Tridax procumbens—one small colony.

Portulaca oleracea and *Melothria maderaspatana,* both occasional.

Origin of the Vegetation

At the end of this paper in Appendix II the species are listed by families, and the plant association to which each belongs is indicated. It will be clear to any one at all familiar with the flora of the Malabar Coast (2, 6) that the species growing on the Reclamations are neither rare nor unusual for this region. The special conditions of the new ground have given some species a chance to get ahead, which are ordinarily suppressed by competition, grazing or human

exploitation. The most remarkable feature of the vegetation is the absence of all but three or four species of the typical Indo-Malay strand forest formation. (7, 8). The seeds of the members of this widespread plant association are chiefly distributed by water (3). Therefore the plants on the Reclamations have not grown from seeds which were in the harbour waters.

The two agents responsible for seed distribution in Cochin Harbour have undoubtedly been wind and birds.

Seeds and fruits adapted to be carried by wind characterise the sedges, the grass *Chloris barbata,* the shrubs *Pajanelia* and *Calotropis,* the trees *Bombax, Alstonia* and *Eriodendron,* as well as eight species of Compositae in the list.

Birds are continually flying back and forth from the shores of the harbour to the islands. They might even fly over from Mattancheri Town on the west, with fruits in their mouths, to eat undisturbed. Crowds of the large and voracious Indian crows come over to the island to eat the wild figs when they are ripe as well as the fruits of *Melothria* and *Passiflora.*

Seeds of several of the plants with fleshy fruits were no doubt brought by birds. Among these are *Passiflora, Melothria, Lantana, Carica papaya* and the *Ficus* species.

Sesbania is grown by the Indian villagers as a prop for the much relished vines of *Piper Betle* L. The seeds should be attractive to birds, and some may fall undigested with their droppings. During the monsoon the ground is very wet, and there would be many opportunities for small seeds to be brought over to the island on the muddy feet of birds. There is no species whose presence cannot be accounted for in some such simple manner.

Drift Seeds

The absence on Willingdon Island of seeds brought as drift by the waters is due to the sea-wall which keeps the flotsam and jetsam off the reclaimed land. It has been stated that the waters are generally calm, and the waves are usually insufficient to lift the debris to the top of the wall.

There is a small curved sand bar about 50 feet long and 10 feet wide, with a declivity between it and the base of the sea wall, on the north shore of Willingdon Island (Plate XIX, Fig. 2). In June 1935 the seeds or fruits of twenty-five species were found on or beside this sand-bar. Most of the species belong to the Indo-Malay strand forest formation, but only one or two of them have gained a foothold on the island. Twigs from two species were striking

root, and a bulb and many rhizomes were found. These are listed in Table III. The rapidity with which plants colonized the sand bar is strikingly shown by comparing the number of species which were growing on 2nd June and again on 18th August (Table IV).

Comparison with Krakatau

It is rarely that we are able to observe the regular successive steps in plant colonization on a new tropical island, however small. When the island of Krakatau in the East Indies blew up and was completely denuded of vegetation in 1883, it gave an opportunity to observe the course of recolonization. Treub was the first botanist to visit the island, he arrived three years after the cataclysm and returned again in 1897 (5 and 9). When Ernst and others went in 1905 and 1906 (1) the island was completely clothed in vegetation Although conditions on the Cochin Harbour Reclamations differ in many ways from those of Krakatau, it is interesting to compare the course of plant colonization in the two places, several species are common to both, and both are in the tropics within the range of the Indo-Malay Strand Flora (7, 8).

The present study was made when parts of Willingdon Island were two and three years old. Some points of comparison are listed below in Table V.

Acknowledgments

I am indebted to R. C. Bristow, Esq., Harbour Engineer-in Chief, and to C. W. Knight, Esq., Bridge Engineer of Cochin Port, for information regarding the reclamations and for the soil analysis data. The staff of the herbarium of the Agricultural College, Coimbatore, have kindly checked all the plant identifications.

Summary

1. Two small islands were reclaimed in Cochin Harbour by dredging material from the harbour floor.

2. The northern part of the larger reclamation (Willingdon Island) was completed in 1932, and in 1935 it was covered with a thick growth of savannah-like vegetation. The southern part was completed in 1933 and different stages in plant colonization therefore coexisted.

3. A brief account is given of the climatic and edaphic conditions. Soil analyses show that there was a high percentage of sodium chloride in the dredged soil, which is rapidly washed out by the monsoon rains.

4. The first colonists on the bare saline sludge are *Fimbristylis spathacea, F. ferruginea* and *F. polytrichoides*. The next are *Mariscus pennatus* and the xerophytie grass *Diplachne fusca*.

5. In the extreme north-west corner of the island there is a crowded association of *Passiflora foetida, Chloris barbata, Tridax* and *Melothria,* with *Sesbania aegyptiaca* as the dominant species on sandy soil and *Mariscus* on loamy soil.

6. Some large trees and saplings of *Ficus* have become established on the piles of oyster shells.

7. Eighty-six species of phanerogams were collected in May and August 1935, and are listed. The species found along five measured linear transepts are also recorded.

8. All species on the reclamations are also found in the region of Cochin Harbour, and the seeds have reached the islands through the agency of wind, birds and man.

9. There is a notable lack of members of the Indo-Malay strand forest formation. The fruits and seeds of twenty-five species were found on a sand-bar beside the reclamation in May 1935. Only four of these were growing on the island. A sea-wall prevents drift-borne seeds from reaching the reclaimed land.

10. A brief comparison is given between the course of plant colonization on Willingdon Island and on Krakatau. Twelve species were found common to both.

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TABLE I*

Percentages of four constituents in soil taken from seven locations on Willingdon Island, Cochin Harbour, January 1935. Samples A are top soil, B and C subsoil at different levels as given in Table II.

Pit No.	Sample.	Total solids.	Soluble organic Matter.	Chlorides as NaCl.	Possibly all sulphates.
1	A	8· 6	1·24	6·73	0·63
	B	4·06	0·55	2·96	0·55
2	A	0·18	0·09	0·08	0·01
	B	0·73	0·14	0·15	0·44
	C	0·12	0·06	0·05	0·01
3	A	2·07	0·26	0·99	0·82
	B	0·53	0·19	0·28	0·06
	C	0·58	0·15	0·34	0·09
4	A	0·3	0·1	0·15	0·05
	B	0·13	0·05	0·07	0·01
	C	0·17	0·04	0·12	0·01
5	A	4·35	0·52	3·48	0·35
6	A	2·12	0·23	1·32	0·57
7	A	0·15	0·04	0·08	0·03
	B	1·36	0·22	0·91	0·25

TABLE II*

Percentage composition of soil samples from Pit 3, Willingdon Island.

Samples	A	B	C
Depth in inches	8	18 — 24	30 — 36
Appearance	sludge	sandy	sandy
Organic matter (loss on ignition)	11·2	1·5	1·4
Physical analysis—			
Coarse sand	0·7	92·7	90·4
Fine sand	28·4	1·2	3·1
Silt	34·6	2·1	3·6
Clay	25 2	2·8	1·8
Moisture	11·1	2·1	1·1

*Figures supplied by the courtesy of the Cochin Port Engineers, for Tables I and II.

TABLE III

Species whose fruits, etc., were found on a sand-bar in Cochin Harbour, May 1935. Species marked * were growing on the reclamation.

1. *Acanthus ilicifolius* L. (seeds and a twig)
2. *Allium* sp. (bulb)
3. *Areca catechu* L. (2 fruits)
4. *Artocarpus hirsutus* Lam. (part of a fruit)
5. *Barringtonia racemosa* Blume (1 fruit)
6. *Bauhinia tomentosa* L. (3 fruits)
7. *Bixa Orellana* L. (1 fruit)
8. **Calonyction bona-nox* Boj. (3 fruits)
9. *Calophyllum inophyllum* L. (numerous fruits)
10. *Canna* sp. (several rhizomes)
11. **Casuarina equisetifolia* L. (2 fruits)
2. *Cerbera manghas* L. (4 fruits)
13. *Cocos nucifera* L. (several fruits)
14. *Enterolobium saman* Prain (3 fruits)
15. *Garcenia morella* Desrouss. (1 fruit)
16. *Hevea braziliensis* Muell. (numerous fruits and seeds)
17. **Luffa aegyptiaca* Mill. (1 fruit)
18. *Mangifera indica* L. (several seeds)
19. *Mesua ferrea* L. (1 fruit)
20. **Pajanelia Rheedii* Wt. (1 fruit)
21. *Pandanus tectorius* Soland. (parts of 4 fruits)
22. *Pongamia glabra* Vent. (4 fruits)
23. *Solanum melongena* L. (1 fruit)
24. *Terminalia catappa* L. (7 fruits)
25. *Thespesia populnea* Corr. (3 fruits and 2 twigs)
26. *Vateria indica* L. (10 fruits)
27. *Phaseolus* sp. ? (2 seeds)

TABLE IV

Vegetation of Sand-bar on beach of Cochin Reclamation, 1935.

2nd June.

* *Acanthus ilicifolius.*
* *Avicenna officinalis.*
Calonyction bona-nox
* *Derris canarensis* Bak.
Diplachne fusca.
Fimbristylis spathacea.

18th August.

More plants of all June species.
* *Cerbera manghas.*
Alternanthera triandra.
Chloris barbata.
Corchorus acutangulus.
Cyperus compressus.
Dactyloctenium aegyptiacum.
Eclipta alba.
* *Enterlobium saman.*
Ipomoea pes-caprae.
Lippia nodiflora.
Melothria maderaspatana.
Paspalidium geminatum.
Passiflora foetida.
Phaseolus adenanthus.
Portulaca oleracea.

Species marked * were not growing on the reclamation.

TABLE V

Comparison between Krakatau in 1886, three years after eruption, and Willingdon Island, Cochin, in 1935 three years after it was reclaimed.

Krakatau.	*Cochin Reclamation.*
Close to the equator.	Latitude 10° N.
Nearest land 19 and 25 kms.	Nearest land a few feet away.
New soil, pumice and volcanic ash, very dry.	New soil silt, sand and shells saturated with sea water.
Blue Green algae prominent first colonists.	Blue Green algae rare and unimportant as first colonists.
Preponderance of ferns.	No ferns.
Prominent strand flora, brought by sea drift to natural beaches.	Nearly all members of strand flora excluded by sea-wall.
Flora of interior also distinct.	All flora of same type.
Seeds brought by water, only a few by wind and birds [21 species or 39·5% in 1897 (5).]	Seeds brought chiefly by birds (61·6%) and by wind.
No plants introduced by man.	Several human introductions (ruderals).
26 species of vascular plants, 15 phanerogams.	86 species of vascular plants, all phanerogams.
1897.	
62 species of vascular plants, 53 phanerogams.	
Seedlings and seeds of 16 species in drift zone. (1886.)	Seedlings and seeds of 44 species found on beach.
1897.	
Seeds and fruits of 26 phanerogams found on beach.	

Appendix I

Analysis of the vegetation along five measured linear transepts on Willingdon Island.

Transept a-b. From back of Malabar Hotel eastward. 2nd June 1935.

1st 100 feet: many plants of *Portulaca oleracea* and *Chloris barbata* in flower. *Sesbania aegyptiaca*—many seedlings 6-18 inches tall. *Ipomoea pes-caprae* — colony with few flowers.

2nd 100 feet and 3rd 100 feet: *Tridax procumbens* — almost pure stand with some *Chloris barbata* and a few *Blumea Wighteana.*

4th 100 feet: *Passiflora foetida* — large colony with *Tridax* and seedlings of *Sesbania, Melothria* and *Lippia.*

5th 100 feet: Species as in 4th 100 feet also *Cassia Tora*, *Mimosa pudica*, *Merremia hastata* and *Sesbania aegyptiaca*.

Transept c-d. From sea-wall 150 feet west of Executive Engineer's garden inland in a south-westerly direction. 2nd April 1935.

1st 50 feet: Cleared ground with one young *Ficus glomerata* and spontaneous *Psidium Guayava*. Several plants of :—*Eragrostis tenella, Chloris barbata, Digitaria longifolia, Eclipta alba, Euphorbia hirta, E. thymifolia, Leucas aspera, Scoparia dulcis, Tridax* and seedlings of *Passiflora foetida*.

2nd 50 feet: Thicket of *Sesbania aegyptiaca* with *Passiflora foetida,* also several plants of *Conyza ambigua, Chloris, Cynanchum, Digitaria* and *Tridax*.

2nd 100 feet: *Ficus religiosa* — one sapling. *Sesbania* association as before with more *Chloris* and *Melothria*. Also plants of *Blumea, Conyza, Vernonia cinerea* and *Physalis minor*.

3rd 100 feet: *Chloris barbata* dominant with *Conyza, Emilia sonchifolia, Passiflora, Tridax, Vernonia* and *Vicoa*. Also a moist depression 15 feet across with *Mariscus pennatus* dominant with *Fimbristylis spathacea* and *F. ferruginea,* and one bush of *Calotropis* 8 feet high.

4th 100 feet: *Mariscus* association replaced by grasses again (*Chloris* and *Eragrostis*) with *Fimbristylis ferruginea, Sesbania aegyptiaca* and *Tridax*. *Lippia nodiflora* — dense colony 20 feet across with scattered plants of *Chloris*. Finally a pure stand of *Imperata* and one large *Ficus glomerata* 30 feet high.

Transept e-f. From the sea-wall on the south-west shore 2,000 feet from north-west end inland across to north-east shore. 19th April 1935.

1st 400 feet: Soft black alkaline soil. Open formation of *Fimbristylis ferruginea, F. spathacea* and large *Festuca* sp. all forming cushions. *Sesbania aegyptiaca* — fifteen stunted seedlings: *Lippia* — one: *Merremia emarginata* — one.

2nd 400 feet: *Fimbristylis* sparse giving way to widely scattered large tufts of xerophytic *Diplachne fusca*.

3rd 400 feet: Continuation of *Diplachne* formation with scattered *Fimbristylis spathacea,* on black alkaline mud. Large sandy area with intermixed shells bearing open association of *Sesbania aegyptiaca, Mariscus, Calotropis, Melothria* and *Passiflora,* also three saplings of *Ficus religiosa,* two of *Bombax,* two plants of *Lactuca runcinata* and one each of *Amaranthus spinosus, Solanum nigrum* and *Physalis minor*.

Last 100 feet: Alluvial soil with colony of *Lippia*, patches of *Chloris*, one clump of *Arundo Donax*, then an association of *Sesbania aegyptiaca, Mariscus, Passiflora, Tridax* and *Blumea lacera* to sea-wall.

Transept g-h. Along top of sea-wall on north-east shore, south-eastwards from Port Trust bungalows. 18th August 1935.

1st 100 feet: Dominant species—*Chloris barbata* with *Sesbania aegyptiaca* a sub-dominant associated with *Tridax, Lippia, Melothria, Corchorus, Euphorbia hirta, Dactyloctenium, Echinochloa* and a few plants of *Fimbristylis ferruginea, Alternanthera, Blumea* and *Sesbania aculeata.*

2nd 100 feet: Same association as before for first 50 feet, then 25 feet of dense colony of *Passiflora* with a few plants of *Chloris, Dichanthium annulatum, Fimbristylis ferruginea* and *Mariscus.* Last 25 feet, a colony of *Mariscus* with a few *Passiflora* vines near the wall.

3rd 100 feet: Dense association of *Mariscus* and *Passiflora* with a few plants of *Vernonia cinerea* and *Blumea Wighteana.*

4th 100 feet: First 25 feet a pure stand of *Mariscus* which is then replaced by *Passiflora* with scattered *Chloris, Brachiaria, Blumea* and *Emilia.* Last 50 feet a pure stand of *Mariscus* with a few grasses and Compositae beside the sea-wall.

5th 100 feet: Pure stand of *Mariscus pennatus* with *Chloris* at edge of wall.

6th 100 feet: 50 feet of pure stand of *Mariscus* with an occasional *Passiflora, Chloris, Blumea* and *Fimbristylis ferruginea* along edge of wall. Also one *Calotropis.* Last 50 feet *Mariscus* association covered with dense growth of *Phaseolus* sp. and a few *Melothria* vines.

7th 100 feet: first 50 feet to jetty: *Mariscus* association with *Phaseolus, Passiflora* and *Melothria.* Saplings: *Ficus religiosa*—1, *Pajanelia*—1, *Tamarindus*—3. 2nd 50 feet, pure stand of *Mariscus* and a colony of *Celerodendron infortunatum* beside the sea-wall.

8th 100 feet: Continuation of *Mariscus,* then colony of *Passiflora,* then an association of *Sesbania aegyptiaca* with *Chloris* and *Fimbristylis spathacea.* One plant each of:—*Ficus gibbosa, F. religiosa, Morinda citrifolia* and *Portulaca.*

9th 100 feet: Open association of *Sesbania aegyptiaca* and *Chloris* with colonies of *Lippia,* some *Tridax,* a few plants of *Mariscus* and *Fimbristylis spathacea,* and a large colony of *Calonyction bona-nox* in centre.

10th 100 feet: Dense pure stand of *Mariscus* and a colony of *Arundo Donax* 50 feet in diameter.

Transept k—l. Inland south-west from sea-wall at jetty 650 feet along transept g-h.

1st 100 feet: *Mariscus* association with large *Phaseolus, Passiflora, Melothria,* a few saplings of *Tamarindus* and one small *Ficus religiosa.* In pathway: *Tridax, Chloris, Dactyloctenium* and *Digitaria.*

2nd 100 feet: *Sesbania-Chloris* association with a few *Calotropis, Passiflora* and *Tridax.* Along pathway: *Tridax, Blumea, Conyza, Phyllanthus Niruri* and *Scoparia dulcis.*

3rd 100 feet: Similar to second 100 feet with pure stand of *Passiflora* on a sand-bank; also a small clump of *Pavonia* and one plant each of: *Carica papaya, Alstonia* and *Lantana*. Along pathway: *Sesbania procumbens, Physalis, Solanum nigrum, Lactuca, Blumea* and *Fimbristylis spathacea.*

4th 100 feet: Open association of *Sesbania* and *Chloris* with *Tridax, Achyranthes, Fimbristylis spathacea, F. ferruginea* and *Melothria.* Sandy soil.

5th 100 feet: As before with a few *Passiflora* and *Chloris* dominant.

6th 100 feet. *Chloris* association on sand with a large colony of *Ipomoea pes-caprae,* a few plants of *Calotropis, Mariscus* and *Sesbania procumbens.*

Appendix II

List of the species found on the Cochin Harbour Reclamations in April, May and August 1935, arranged by families. The association to which each belongs is indicated by a letter in column two. The agent which probably brought the seeds is given in column three. The nomenclature is that of Gamble (2) and Fisher. Species reported for Krakatau by Penzig (5) and Ernst (1) marked†. Species found on Edam Island near Java by Ernst (1) marked with*

Explanation of symbols in Column 2: C=*Chloris* association, F=*Fimbristylis* association, Fi=*Ficus* association, M=*Mariscus* association, R=Ruderal, S=*Sesbania* association. Dominants printed in bold type.

Family	Genus and species	Association	Dispersal Agent.
Portulacaceae	**Portulaca oleracea* L.	C & R	Birds
Malvaceae	*Bombax malabaricum* DC.	S	Wind
	Eriodendron pentandrum Kurz.	S	,,
	Pavonia odorata Willd.	S	Birds
	Sida acuta Burm.	C	,,
	Urena lobata L.	S	,,
Tiliaceae	*Corchorus acutangulus* Lam.	S	,,

Family	Genus and Species	Association	Dispersal Agent.
Sapindaceae	†*Dodonia viscosa* L.	S	Birds
Leguminosae	*Acacia arabica* Willd.	C	,,
	Cassia Tora L.	R	,,
	?*Phaseolus adenanthus* G. F. Mey.?	M	,,
	Mimosa pudica L.	R	,,
	Sesbania aculeata Pers.	S	,,
	S. aegyptiaca Pers.	S	,,
	S. procumbens W. & A.	S	,,
	Tamarindus indica L.	M & S	,,
Myrtaceae	*Psidium Guayava* L.	R	,,
Passifloraceae	†*Carica papaya* L.	S	,,
	**Passiflora foetida* L.	M & S	,,
Cucurbitaceae	*Luffa aegyptiaca* Mill.	C	,,
	Melothria maderaspatana Cogn.	S	,,
Rubiaceae	*Bourreria hispida* K. Sch.	C & R	Wind?
	†*Morinda citrifolia* L.	M & R	Birds
Compositae	†**Blumea lacera* DC. var. *glandulosa* H.f.	Fi. & S	Wind
	B. Wighteana DC.	,, ,, ,,	,,
	†**Conyza ambigua* DC.	Fi. S & R	,,
	**Eclipta alba* Hassk.	R & S	Birds?
	†*Emilia sonchifolia* DC.	M & S	Wind.
	Lactuca runcinata DC.	C	,,
	Sphaeranthus indicus L.	F	Birds?
	**Tridax procumbens* L.	Fi., R & S	Wind
	†**Vernonia cinerea* Less.	C. R & S	,,
	Vicoa indica DC.	C	,,
Apocynaceae	*Alstonia scholaris* R. Br.	S	,,
	?*Plumerea acutifolia* Poir.	S	,,
Asclepiadaceae	**Calotropis gigantea* R. Br.	S	,,
	Cynanchum calliata Ham.	S	,,
	Leptadenia reticulata Wight	Fi.	,,
	Marsdenia volubilis T. Cooke (Syn. *Dregia volubilis* Benth.)	M	,,
Convolvulaceae	*Calonyction bona-nox* Boj.	M	Birds
	Ipomoea reptans Poir (Syn. *I. aquatica* Forsk.)	C	,,
	†**I. pes-caprae* Sw.	C	,,
	Merremia hastata Hall. f. (Syn. *Ipomoea angustifolio* Jacq.)	S	,,
	M. emarginata Hall. f. (Syn. *Ipomoea reniformis* Chois.)	F	,,
Solanaceae	*Physalis minima* L.	C, R & S.	,,
	Solanum nigrum L.	C & S	,,
Scrophulariaceae]	*Scoparia dulcis* L.	R & S	Wind?
	Vandellia crustacea Benth.	C & R	,,
Bignoniaceae]	*Pajanelia Rheedii* Wt.	Fi.	,,
	?*Tecoma undulata* G. Don.	S	,,
Verbenaceae	*Clerodendron infortunatum* L.	M	Birds
	**Lantana aculeata* L. (Syn. *L. Camera* L.	R	,,
	Lippia nodiflora Mich.	S	Wind
Labiatae	*Leucas aspera* Spreng.	R & S	Birds
Nyctaginaceae	*Boerhaavia diffusa* L.	C & R	Wind?

Family	Genus and Species	Association	Dispersal Agent.
Amarantaceae	*Achyranthes aspera* L.	Fi. M & S	Wind ?
	Alternanthera triandra Lamk. (Syn. *A. sessilis* R. Br.)	R	Birds
	Amaranthus viridis L.	R	,,
	A. spinosus L.	C	,,
Euphorbiaceae	*Breynia rhamnoides* Muell.	Fi	,,
	†*Euphorbia hirta* L. (Syn. *E. pilulifera* L.)	R	,,
	E. thymifolia L.	R	,,
	Phyllanthus Niruri L.	R	,,
	Sebastiana chamaelea Muell.	R & S	,,
Moraceae	*Ficus bengalensis* L.	Fi	,,
	F. gibbosa Bl., var. *parasitica* Koen.	M	,,
	F. glomerata Roxb.	Fi & S	,,
	F. religiosa L.	Fi, M & S	,,
	F. Tsiela Roxb.	Fi	,,
Casuarineae	†*Casuarina equisetifolia* Forst.	S	,,
Cyperaceae	*Cyperus compressus* L.	R & S	Wind
	Fimbristylis ferruginea Vahl.	F & M	,,
	F. polytrichoides R. Br.	F.	,,
	†****F. spathacea*** Roth.	F	,,
	****Mariscus pennatus*** Don.	M	,,
Gramineae	*Arundo Donax* L.	M	,,
	Brachiaria distachya Stapf. (Syn. *Panicum distachyum* L.)	C & R	Birds
	Chloris barbata Sw.	C, R & S	Wind
	Dactyloctenium aegyptiacum Beauv. (Syn. *Eleusine indica* Gaertn.)	R & S	Birds
	Dichanthium annulatum Stapf. (Syn. *Andropogon annulatus* Forsk.)	S	Wind
	Digitaria longifolia Pers.	R	Birds
	Diplachne fusca Beauv.		
	Echinochloa colona Link.	S	,,
	†*Eragrostis tenella* R. & S. var. *plumosa* Stapf.	R & S	Wind
	Imperata cylindrica Beauv. var. *Koenigii* Desv.	M	,,
	Paspalidium geminatum Stapf.	R	,,

Total Number of species — 86.
Number brought by birds — 53.
Do. do. wind — 33.

Explanation of Plates

PLATE XVIII.

Fig. 1. Vegetation on north-west end of Willingdon Island. *Mariscus* in front, a colony of *Imperata* and a tree of *Ficus globosa* behind.

Fig. 2. *Sesbania-Passiflora* association with large *Ficus globosa.*

Fig. 3. Willingdon Island seen from sand-bar on north shore. *Calonyction Bona-nox* climbing on sea-wall.

Fig. 4. *Mariscus* association with *Phaselous* sp. Sapling of *Ficus religiosa* on left, small *Tamarindus* on right, in background *Arundo Donax* on top of sea-wall.

PLATE XIX.

Fig. 1. *Calotropis* invading *Fimbristylis* pioneer association on marl. Vypeen Reclamation.

Fig. 2. *Ficus* association on oyster shells.

Fig. 3. *Mariscus* and *Tamarindus* invading *Fimbristylis* pioneer association on Vypeen Reclamation.

1

2

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4

E. W. ERLANSON—*PLANT COLONIZATION.*

1

2

3

E. W. ERLANSON—*PLANT COLONIZATION.*

REVIEWS

COOPER, D. C. Macrosporogenesis and development of the embryo sac of *Lilium Henryi.* Bot. Gaz. *97*: 346-355. 1935.

Until recently it used to be thought that in *Lilium* the development of the embryo sac was of a very simple type. Treub and Mellink (1880) reported that in *Lilium bulbiferum* the megaspore mother cell does not form the usual tetrad of megaspores, but undergoes only three nuclear divisions (against the usual five) to give rise to an eight-nucleate embryo sac. Although the final appearance is similar to that of the normal type of embryo sac found in the majority of angiosperms, it differs from the latter in the fact that all the four megaspore nuclei take part in the development and undergo just one more division. After Treub and Mellink's discovery, this method of development was reported in many other plants and for the sake of convenience it has been called the "Lilium-type."

A thorough investigation of the embryo sac of *Fritillaria persica* (BAMBACIONI, 1928) showed that instead of the egg being removed from the megaspore mother cell by three divisions, four divisions actually intervene. After the second division is over (*i.e.*, at the 4-nucleate stage), three of the reduction nuclei pass to the chalazal end of the embryo sac leaving the fourth at the micropylar end. All of them divide simultaneously, but the three chalazal spindles fuse to form one large common spindle and after this division there are again only four nuclei in the embryo sac. In this second four-nucleate stage the two micropylar nuclei are haploid while the other two are triploid. The fourth division proceeds in the normal way and a group of four haploid nuclei is formed at the micropylar pole and four triploid nuclei at the chalazal pole.

BAMBACIONI-MEZZETTI (1932) reported the same type of development in two species of *Lilium* and COOPER has now seen it in 10 spp. of this genus. Dr. Donald A. Johansen of Stanford finds the same thing in two other species, although his observations are not yet published. It is interesting to note that Guignard (1891), Coulter (1897), Sargant (1896) and Mottier (1898) saw some abnormal appearances (pointing towards the same conclusion) in the species of *Lilium,* which they studied, but they thought these to be caused by some physiological conditions and failed to pursue the point further.

As Dr. Cooper says, there is a very strong evidence to support the conclusion that the history of embryo sac development reported by him is characteristic of the genus *Lilium* as a whole. In the reviewer's opinion it now appears advisable to discard the name "Lilium-type" altogether. What we so far understood by

this term, should now be called the "Adoxa-type," since *Adoxa moschatellina* (Jönsson, 1879/1880) was really the first plant, in which all the four megaspore nuclei were observed to divide once to give rise to an eight-nucleate embryo sac; and a new name "Fritillaria-type" should be instituted for the inclusion of embryo sacs such as those of *Fritillaria persica, Tulipa gesneriana, Myricaria germanica* and spp. of *Lilium*. Species of *Euphorbia* and *Piper* and any other plants, in which the figures of previous authors show a considerable difference between the relative sizes of the micropylar and chalazal nuclei, will probably reveal interesting features on a reinvestigation.

P. Maheshwari.

Baird, Thelma T. Comparative Study of Dehydration. Stain Technology *11*: 13-22. 1936.

During the last ten years many improvements have been made in the methods of fixation of material, bringing it into a suitable condition for embedding in paraffin, and finally the staining of the sections to bring out the desired details. Several substitutes have been tried for the usual alcohol-xylol series and some of these have turned out to be very valuable for special kinds of work.

In this paper Dr. Baird of the Ohio State University presents the results of his trials with several dehydrating agents and concludes that "while dioxan (diethyl dioxide) does not completely fulfil the dreams of a microscopist for a perfect dehydrating agent, yet it is definitely superior to any known substance."

The use of this substance in microtechnique is a very recent development. Perhaps it was first announced only 5 years ago by two German Zoologists, Graupner and Weissburger (see Zool. Anzeiger, 1931). It is a "colourless liquid with a faint odour, a boiling point of 101° C and melting point of 8° C. Its specific gravity is near that of water (1·0418) and its volatility rather high. It is miscible in all proportions with water and alcohol. It dissolves paraffin slightly when cold, but quite readily when heated."

Graupner and Weissburger transferred the material directly from water to dioxan, but the following procedure recommended by Baird seems to the better because it is more gradual:

1. Fix material in the desired fluid.

2. Wash in running water.

3. Carry on to pure dioxan after using two or three intermediate grades containing mixtures of water and dioxan; 2 hours in each.

4. Change dioxan once.

5. Place vial in an incubator at a temperature of 40° C, adding paraffin chips now and then.

6. After 12 to 24 hours transfer to pure paraffin, changing twice.

7. Embed.

The following are the advantages claimed for this method: (1) The time taken to get the material into paraffin is appreciably shorter; (2) The tissues do not become hardened, which is almost always the case in alcohol and xylol; (3) a wide time variation is possible and no damage is done if the material remains longer in dioxan than specified; (4) There is no shrinkage, unless it has been caused previously by the fixative. The author reports that root-tips of *Allium* showed less shrinkage with the dioxan method than with any other.

Botanists, whose attempts to cut vegetative organs of plants by the usual methods are often foiled, might give a thorough trial to this method. It would of course be necessary to keep the material for longer periods in the water-dioxan mixtures and also in paraffin, since the cell-wall in plants does not allow easy penetration. For material fixed in formation-acetic-alcohol and other alcoholic fluids, it should be quite possible to prepare a few intermediate grades of alcohol and dioxan, since the two are miscible in all proportions.

Pure dioxan can be obtained at about Rs. 10 per lb. from the British Drug Houses Ltd., Grahan Street, City Road, London N.I. The reviewer has used commercial dioxan (sold at Rs. 5 per lb.) and the results are quite encouraging.

P. MAHESHWARI.

WODEHOUSE, R. P. "Pollen grains: their Structure, Identification and Significance in Science and Medicine". (McGraw-Hill Book Co., Inc., New York and London, 1935). Pp. xv + 574, 14 plates. Price 36*s*.

DR. R. P. WODEHOUSE, Director of the hayfever laboratory of the Arlington Chemical Company, Yonkers, New York, has now brought to a brilliantly successful termination the work which he started about 20 years ago.

Observations on the shape and appearance of pollen grains started soon after the discovery of the compound microscope and some of the older workers studied them with great vigour and enthusiasm, but during recent times only a few have been attracted by this line of work. DR. WODEHOUSE's interest in the subject

was aroused entirely by practical and humanitarian considerations — by the part which many kinds of pollen grains play in the production of hayfever—, but his method of approach has been throughly scientific and he is to be congratulated on the production of a work which gives such an amount of valuable information on "Pollen grains: their structure, identification and significance in science and medicine".

The first part of the book begins with a long but very charmingly written historical resumé of the work done by older workers with some interesting anecdotes about their private lives. The next two chapters deal with the collection and preservation of pollen and its preparation for microscopic examination. Chapter iv is contributed by Dr. G. Erdtman of Stockholm, a pupil of Prof. L. von Post, of the same University, who was probably the first to perfect the technique of peat sampling and the use of "pollen statistics" in revealing post-glacial vegetational changes.

A very full account, extending to more than 25 pages, is given of atmospheric pollen and the part it plays in the incidence of hay-fever in the United States. Methods of diagnosis of the disease and its treatment are also described briefly, but the author is careful enough to warn the inexperienced from attempting them. Although not of much importance in India, this disease demands attention from Botanists in such parts of the world where it is prevalent. Clear and exhaustive directions are given for preparing charts and pollen surveys for the benefit of those who might care to take up such work. This part of the book then closes with a very useful account of the general morphology of pollen.

Part 2 is of greater interest to the specialist. It commences with a key for the identification of pollen of such families and genera which are described afterwards in detail. "In the discussions of the families are described the form of the grain that is basic for the family and from which the others might have been derived and, as far as known, the inter-relationships of the various forms to each other, and the evolutionary tendencies manifest in the group". The part dealing with the Fossil and Living Gymnosperms appears to be most exhaustive in this respect.

The illustrations are fine, and one who has seen some of Dr. Wodehouse's own preparations (sent as a present about 12 months ago) cannot fail to be impressed by their accuracy.

The book certainly "presents as far as possible what is known about pollen grains". There are still great gaps in our knowledge. The author admits in the very beginning that "at the present time the discovered is but a small part of the discoverable in pollen morphology." It is to be hoped that Dr. Wodehouse's work will stimulate a sufficient number of investigations to make the second editions much fuller than the first one and that "Pollen

Grains" will provide us with a new method of approach for the taxonomy of flowering plants; comparable to vegetative anatomy and embryology. As the author says, 'pollen grains are as much a part of the plant as the various organs upon which the taxonomist has drawn to build his imaginative and surprisingly beautiful classification. But in this he has consistently ignored the pollen grains. In his rejection of them he has thrown away, perhaps, the richest part of his heritage, for in no other part of the plant are to be found packed in so small a space so many readily available phylogenetic characters'.

P. MAHESHWARI.

COULTER, M. C. The Story of the Plant Kingdom. The University of Chicago Press, Chicago, Illinois, 1935. Pp. 270. $2·5.

The famous author has prepared this book for the University of Chicago to provide an introduction to Biology as well as to form a part of general reading to provide "a respectable minimum of general education." The story of the plant kingdom has been well told and will be appreciated not only by beginners and lay readers but even the advanced students will derive pleasure and benefit by reading it.

The generous footnotes constitute a notable feature of the Book. Although they "provide qualifications, amplifications and speculations that are felt to be wholesome mental fodder for the student," they do detract the reader from the main theme in spite of the author's advice to the contrary. All the information or speculation in the footnotes could be absorbed in the main sketch and we hope this will be done in the second edition of the book, which is sure to come in the near future.

This, however, does not detract from the worth of the book which should find a place in every public and private library.

P. PARIJA.

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STUDIES IN INDIAN LIVERWORTS : A REVIEW*

BY

S. K. PANDE, D.SC.

Department of Botany, Lucknow University, Lucknow

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Contents

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I. Introduction and Historical Review

The liverworts have generally been assigned an important position in the evolution of plants. Morphologically also they show a great range of variations in the structure of the gametophyte as well as the sporophyte. For these reasons the group has attracted the attention of many botanists in Europe and America. In India, however, only a belated interest has been shown in the study of these plants.

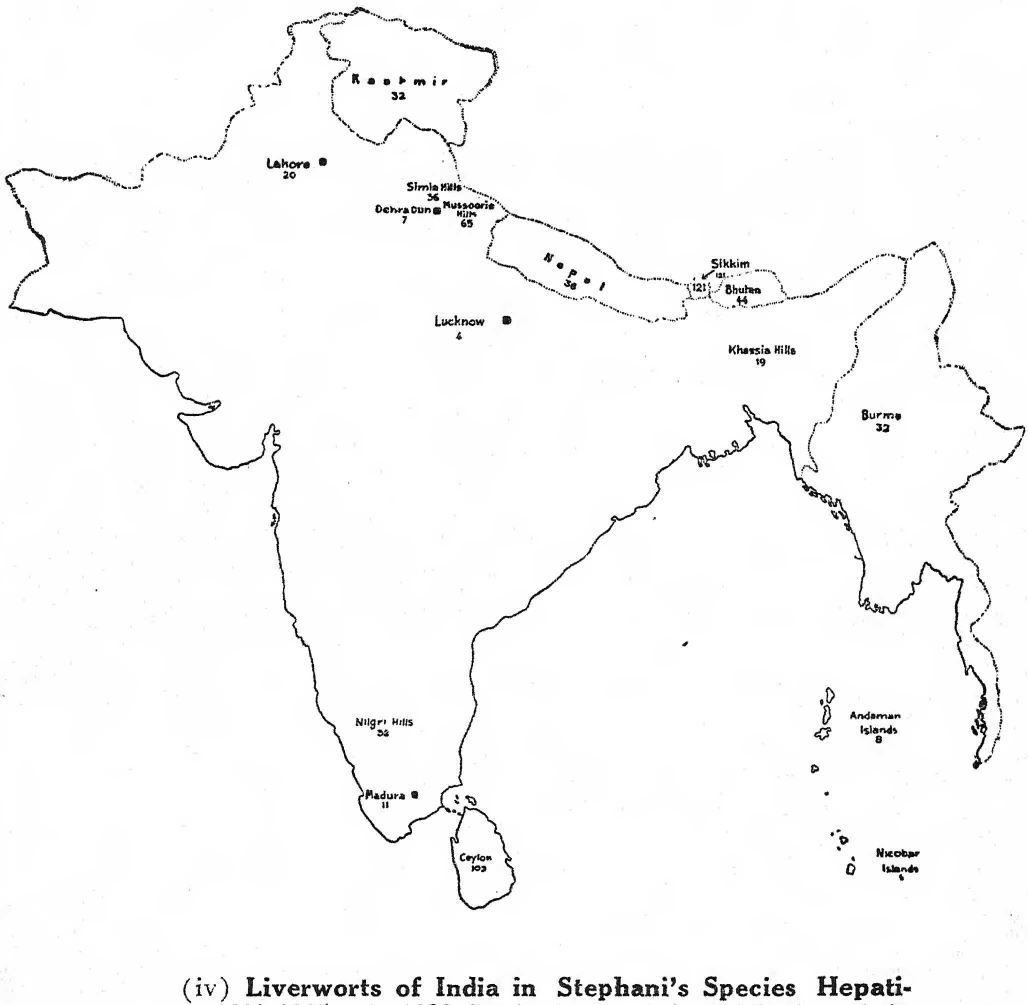
(i) **Early records of Liverworts of India and Griffith's contributions.**—The earliest record of the Indian liverworts, apart from those collected by Dr. Wallich and Wight and described later in the Synopsis Hepaticarum of Gottsche, Lindenberge et Nees (10), is a brief reference by Royle in the well known "Illustrations of the Botany and other Branches of Natural History of the Himalayan Mountains, Vol. I, 1839" (41). By this time William Griffith, who was originally an assistant surgeon in Madras, had already commenced his studies of the Indian Liverworts. In 1835 Griffith accompanied Dr. Wallich, who was then in charge of the Botanic Gardens at Calcutta, on an expedition to Assam in order to inspect the localities in which the tea plant grew wild (34). During this and the following year he made valuable collections from this region. Subsequent additions to these were made from Burma in 1837 and from Bhootan in 1838. It was chiefly during these excursions and during his short tenure of office as Superintendent of the Royal Botanic Gardens at Calcutta that Griffith compiled his valuable notes, "Notulae ad Plantae Asiaticae," with the accompanying set of plates, which were published after his death in 1849 as his Posthumous Memoirs (11, 12). About 50 species of liverworts are described in these works.

(ii) **Mitten's Work,** 1861.—In 1861 Mitten produced a comprehensive account of the Indian Liverworts in the Journal of the Proceedings of the Linnean Society (32). In these papers he presented a concise systematic account of all the species collected by Sir J. D. Hooker in the Himalayas and by Sir Joseph Hooker and Dr. Thomson in the Khasia Hills, as well as those gathered by Gardner and Thwaites in Ceylon. He has also included all the species described by Griffith in the Notulae ad Plantae Asiaticae and those described from India in the Synopsis Hepaticarum.

Since the publication of Mitten's work till about the close of the last century apparently no work was done on Indian liverworts except for collections by systematists, forest botanists, surveyors and travellers, prominent among whom were Brandis, Duthie, Gamble, Hartless, Bretaudeu, Gammie, Perrottet, Decoly and Schaul and Durel.

(iii) **Schiffner's work on Liverworts of Bhootan**, 1899.—Durel's collection was made in 1898 from British Bhootan between

Maria Basti and Labar at a height of 5,000-6,000 ft. and subsequently described by Professor Schiffner in 1899 (42). Out of the 35 species of liverworts described in this paper 10 species and 2 varieties were new to science.



(iv) **Liverworts of India in Stephani's Species Hepaticarum**, 1898-1925.—In 1898 Stephani started the publication of the Species Hepaticarum which deals with the liverwort flora of the whole world. The last volume of these comprehensive works was published in 1925. A census taken from Stephani's publications (44) reveals that out of about 525 species of liverworts occurring in India more than half are endemic.

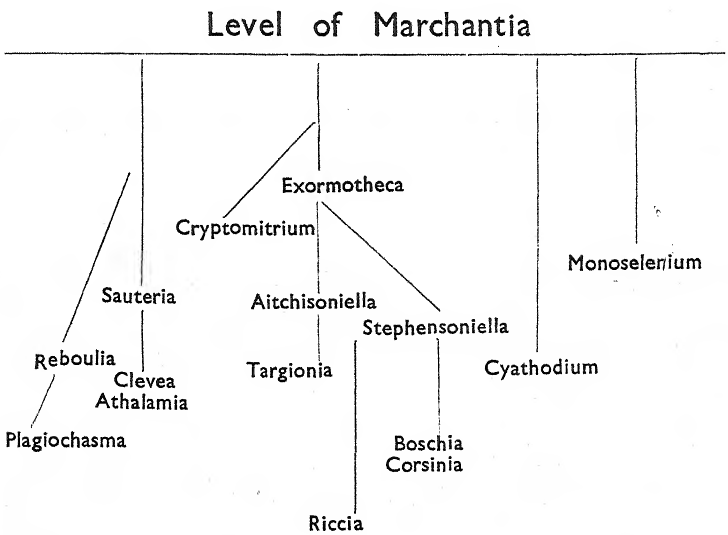
The following list and map gives the number of liverworts in some of the important localities on the basis of the data available in the Species Hepaticarum, supplemented from other works:—

1.	Sikkim	121
2.	Ceylon	103
3.	Mussoorie	65
4.	Bhootan	44
5.	Nepal	36
6.	Simla	36
7.	Kashmir	32
8.	Nilgiri Hills	32
9.	Burma	32
10.	Lahore	20
11.	Khasia Hills	19
12.	Madura	11
13.	Andamans	8
14.	Dehra Dun	7
15.	Nicobar	5
16.	Lucknow	5

In 1910 appeared a paper by Goebel on *Monoselenium tenerum,* a liverwort originally described by Griffith from Assam (11, 12). This plant was accidently transported to München (probably as spores) along with some tea plants which were obtained from Canton (34). The tea plants died but the soil was kept moist in the hope of germinating seeds, when *Monoselenium* turned up (34). As a result of his studies of this interesting liverwort Goebel was led to the important conclusion that the simpler members of the Marchantiales have been derived from the higher ones by reduction (8).

(v) **Kashyap's contributions,** 1912-1934.—About 1912 the late Prof. S. R. Kashyap, who will always be remembered as the father of Bryology in India, began his critical studies of the Indian liverworts and in 1914 was published his first paper "Morphological and biological notes on new and little known West-Himalayan liverworts," in the New Phytologist (13). The other two papers of this series were published later in the same journal (14, 15). In these papers Professor Kashyap enumerated 28 species of liverworts from this area and of these three genera and several species were new to Science. In the light of his studies of these Himalayan forms he strongly supported Goebel's view of reduction in the Marchantiales and added new facts in support of it (13-15). The

Indian liverworts provided him sufficient data to trace the details of reduction in several cases as shown below:—



Phylogeny of Marchantiales as suggested by Kashyap.

The results obtained by Kashyap from his investigations of other groups (13-17) convinced him of a wholesale reduction in the Hepaticae and he put forth ample evidence in support of this view in his Presidential Address to the Botany Section of the Sixth Indian Science Congress at Bombay in 1919 (18).

In 1920 (19) and 1921 (20) Professor Kashyap published accounts of the distribution of liverworts in the Western Himalayas and Ladak, embodying the results of his extensive travels in these regions.

An illustrated account of the Liverworts of the Western Himalayas and the Panjab Plain (Part I) was brought forth by Kashyap in 1929 (21). The second part of this valuable work, written in collaboration with Mr. R. S. Chopra, appeared in 1932 (23). These publications (21-23) have added greatly to our knowledge of the Indian Liverworts, especially those from the Himalayas, and they are of great help to the students of Indian Bryology. In all about 53 genera and 161 species were described and of these 4 genera and about 50 species were founded by Professor Kashyap himself.

(vi) **Gola's paper on Kashmir Liverworts,** 1914.—In 1914 a short note was published by Gola on the Liverworts of Kashmir (9). Eleven species were enumerated in this note and of these three were new to science.

(vii) **Other contributions to Indian Bryology.**—In addition to the works of the authors referred to above, contributions have also been made by Kashyap and Pandé (24), Sethi (43), and Chowdhury and Rajaram (5) from Lahore, Khanna (25-29) from Rangoon, Tiwari (46) from Benares, and Müller (33). A paper has also been published by Chalaud from Toulouse on "Mycorrhiza and tuberisation in *Sewardiella tuberifera*" (6). In his monograph, "Die Frullaniaceae der Indomalesischen Inseln" (48), Verdoorn has included a number of species of this interesting family from India. He has also published important information on some Indian Liverworts in the "Hepaticae Selectae et Criticae", series I and II (49) and III and IV (50).

(viii) **Work done by the author.**—In 1921 the author commenced his studies of the Indian liverworts. It was felt that a detailed investigation of some of the Indian types was very necessary not only because it may place students in Indian Universities, where Botany was becoming popular day by day, in possession of first-hand detailed knowledge of the local plants, but also because it may lead to further elucidation of certain important bryological problems. The following types were selected for this study:—

A. Anthocerotales.

1. *Notothylas indica* Kashyap.
2. *N. levieri* Schiffner MS.

B. Jungermanniales.

3. *Fossombronia himalayensis* Kashyap.
4. *Aneura indica* St.

C. Marchantiales.

5. *Riccia robusta* Kashyap.
6. *R. sanguinea* Kashyap.

The results of my investigations of these plants have been communicated to different sessions of the Indian Science Congress and in some cases have also been published in final form (24, 36-40).

(ix) **Future work.**—Turning our attention to the future researches in Indian Hepaticology it may be said that there is a great field for many interesting and fruitful lines of investigation. The lofty Himalayas and the rain forests provide an ideal home for the growth of liverworts and a record of 525 species from India certainly represents only a fraction of the Hepatic vegetation. Further collections and their systematic examination on the lines begun by the late Professor S. R. Kashyap will surely lead to useful results.

Another and undoubtedly a more important line of research would be a detailed investigation of the life-history of some of the new and interesting genera and species especially the intermediate and the connecting types like *Sewardiella, Aitchisoniella, Stephen-*

sonicila, etc. Prof. Kashyap was able to make use of the material he investigated for a fresh study of the relationships. Further studies might reveal striking results which would be helpful in the elucidation of the relationships and the phylogeny of this interesting group of plants.

Still another aspect of future investigation is the study of this group in its natural habitat, from the ecological, physiological and distribution points of view.

II. Some general considerations

In the foregoing pages an attempt was made to summarise our present knowledge of Indian Hepaticology. My observations on the different species studied are given along with their published accounts. Certain considerations of general interest may be briefly reviewed here.

(*a*) **Distribution of Liverworts in the Himalayas.**—One of these interesting problems is the distribution of liverworts in the Himalayas. Professor Kashyap has shown (19, 20) that in the Western Himalayas

(i) in the outer range the number of species of liverworts, as well as the number of individuals of a particular species at a given altitude, decreases from the East to the West,

(ii) in passing vertically upwards from the plains the number of liverworts increases up to a height of 7,000 ft. in the outer Himalayas, after which it decreases; further that the same law holds good for the middle and inner ranges,

(iii) the number of liverworts in the middle ranges is less than that in the outer Himalayas and

(iv) there are no liverworts beyond the inner ranges.

Sufficient evidence is available in support of the above from the facts at present known. In the accompanying list is given the number of liverworts from some of the important localities in the Himalayas.

Locality		*Height above Sea level*	*Number of species of liverworts*
Eastern Himalayas	Sikkim ..	7,000 — 8,000 ft.	121
	Bhootan ..	6,000 — 7,000 ft.	44
	Nepal ..	6,000 — 7,000 ft.	36
Western Himalayas	Mussoorie ..	6,000 — 8,000 ft.	65
	Simla ..	6,000 — 8,000 ft.	36
	Kashmir Valley ..	Variable.	32

A perusal of the above table shows that the liverwort flora becomes poorer in the Western Himalayas as we proceed from Mussoorie in the east to Kashmir in the west. Probably the same law may hold good for the Himalayas as a whole, including the localities in the Eastern Himalayas, as is evident from the fact that

the number of liverworts recorded from Sikkim is 121, a figure which is almost double the number recorded from any other locality at the corresponding height to the west of it, although the flora of some of these localities has been more thoroughly explored.

The reason that the number of liverwort species recorded from Bhootan and Nepal is so low is probably because the flora of these independent territories is yet very imperfectly known. More extensive collections, especially from the Eastern Himalayas, are likely to add more facts which would supplement these data. Professor Kashyap's view also appears to hold good for the vertical distribution of these plants. My own experience of the liverwort flora of the Kumaon hills and certain parts of the Western Himalayas has led me to the same conclusion. At Dehra Dun which lies at the base of the Mussoorie Hills, only six or seven species of liverworts are found, but the number increases as we ascend to Mussoorie (7,000-8,000 ft.) where as many as 65 species are known to occur. A similar condition is also found in certain other parts of the Western Himalayas. Thus at Kathgodam, which is situated at the foot of the Naini Tal hills, only a few liverworts are met with, while at Naini Tal itself (7,000-8,000 ft.) the liverwort flora is very rich. Beyond a height of about 8,000 ft. in the outer Himalayas the liverwort flora becomes poorer.

Our knowledge of the liverwort flora of the higher altitudes and the interior of the Himalayas is yet far from complete, but whatever is known at present supports the conclusions arrived at by Professor Kashyap with regard to the distribution of this group in these regions.

(*b*) **Reduction as a factor in the origin of simpler liverworts.**—The question as to whether the simpler members of the Hepaticae have given rise to more complex ones by gradual evolution and amplification, or whether, on the contrary, the former have arisen from the latter by reduction and simplification, is one that has frequently been discussed. Underwood (47), Campbell (3), Cavers (4), Lotsy (31) and Bower (2) have argued in favour of the former view. The opposite view has gained prominence since the publication of Professor Goebel's researches on *Monoselenium tenerum* (8). Prof. Kashyap has greatly amplified this from his studies of the Indian liverworts (13-15, 18). While it cannot be denied that an important problem such as this could only be properly discussed after a comprehensive investigation of many more genera and species of the different groups of liverworts and while I am also fully aware of the limitations of my own work in this connection, yet certain interesting features observed by me in some of the species investigated induce me to say a few words on the subject so far as it concerns those particular cases.

In my work on *Notothylas levieri* Schiffner, I had occasion to refer to this point (40). The structure of the capsule and its mode of dehiscence are features of special interest. As usual in

the genus, the sporogonium in both the Indian species studied (*N. indica* Kash. and *N. levieri* Schiffner) is horizontal and ensheathed in an involucre and although valves capable of hygroscopic movements and provided with well developed sutures for dehiscence are present, the spores are generally liberated by the decay of the capsule wall. In some cases, however, the sporogonia may dehisce normally but even here the dehiscence occurs generally only along one of the sutures. This imperfect mode of spore-liberation, even when there is an efficient provision for normal dehiscence, together with the fact that the sporogonial wall contains photosynthetic tissue although there are no stomata, would indicate that *Notothylas* is a reduced genus, a view which has been held by some other bryologists (1, 7, 21). I have shown conclusively that in *N. levieri,* the only noncolumellate species which has so far been fully investigated, the sporogenous tissue is derived only from the endothecium; while in *N. indica* it is formed from the amphithecium, and the endothecium gives rise to the columella as in *Anthoceros*. If our reasoning is correct and if we are justified in regarding *Notothylas* as a reduced genus, the obvious conclusion would be that the columellate species are comparatively primitive (least reduced) while the non-columellate are relatively more advanced (most reduced). This would mean that the amphithecial archesporium is a primitive character and the endothecial archesporium a reduced character. This might possibly also indicate that the Anthocerotales, in all of which (except some species of *Notothylas*) the sporogenous tisue arises from the amphithecium are primitive; while the Jungermanniales and the Marchantiales, etc., in which the sporogenous tissue arises from the endothecium, are reduced. But it must be borne in mind that we cannot generalise without more intensive work on a fairly large number of genera and species of different groups. However, it seems quite reasonable to suppose that *Notothylas* is a reduced genus in which the columellate species, like *N. indica,* are primitive, while the non-columellate species, like *N. levieri,* are reduced. A full discussion of this question is given in my paper on *Notothylas levieri* (40).

Another case to which I might refer here is that of *Riccia robusta* Kashyap. This plant, which had previously been investigated by Kashyap (16) and others (30, 35), was recently studied by me (38). It seems that the scales may be present in this species under certain conditions but not under others. Even in those cases when these are present they are small, rudimentary, deciduous structures confined to the apex. It does not seem at all unlikely that these organs represent the vestiges of once well developed functional scales. According to Professor Kashyap, in the specimens of this species from Lahul, there are no tuberculate rhizoids (21). In *R. crystallina,* which appears to be synonymous with *R. robusta* St. Nicholson, (33a, p. 142), Pagan noticed small sterile nutritive cells (35); but they have not been seen by others. This might be due

to the fact that they are formed only occasionally. Another interesting feature of *R. robusta*, as I have pointed out elsewhere (38), is that sometimes two archegonia are found together in a single chamber. This may only be one of the many abnormalities abundant in the plant-kingdom, or it might indicate the recurrence of an ancestral character, thereby suggesting the origin of *Riccia robusta* from ancestors in which the archegonia were grouped together. In any case, all the above features of *R. robusta* taken together would tend to indicate that the species is reduced.

A consideration of cases like those outlined above seems to make it apparent that reduction has played an important part in the origin of the simpler members of the Hepaticae.

III. Acknowledgments

I cannot adequately express my indebtedness to Professor B. Sahni, at whose suggestion the work was originally begun, for all the kindnesses during the course of my investigations. Not only have I had the benefit of his kindly advice and criticism but also a free access to his valuable personal library. I am also extremely grateful to him for placing at my disposal his valuable and well fixed material of *Fossombronia himalayensis* Kashyap. My grateful thanks are also due to the late Professor S. R. Kashyap, with whom I had the privilege of being associated both as a student and a joint worker, for many helpful suggestions and criticisms, as well as for the identification of some of the specimens from my own collections. I also wish to record here my thanks to Messrs. R. S. Sharma and V. S. Sharma for help in the preparation of some of the drawings and photographs reproduced here and elsewhere.

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ON INDIAN SPECIES OF THE GENUS *ANTHOCEROS* LINN. WITH A DESCRIPTION OF A NEW SPECIES FROM TRAVANCORE

BY

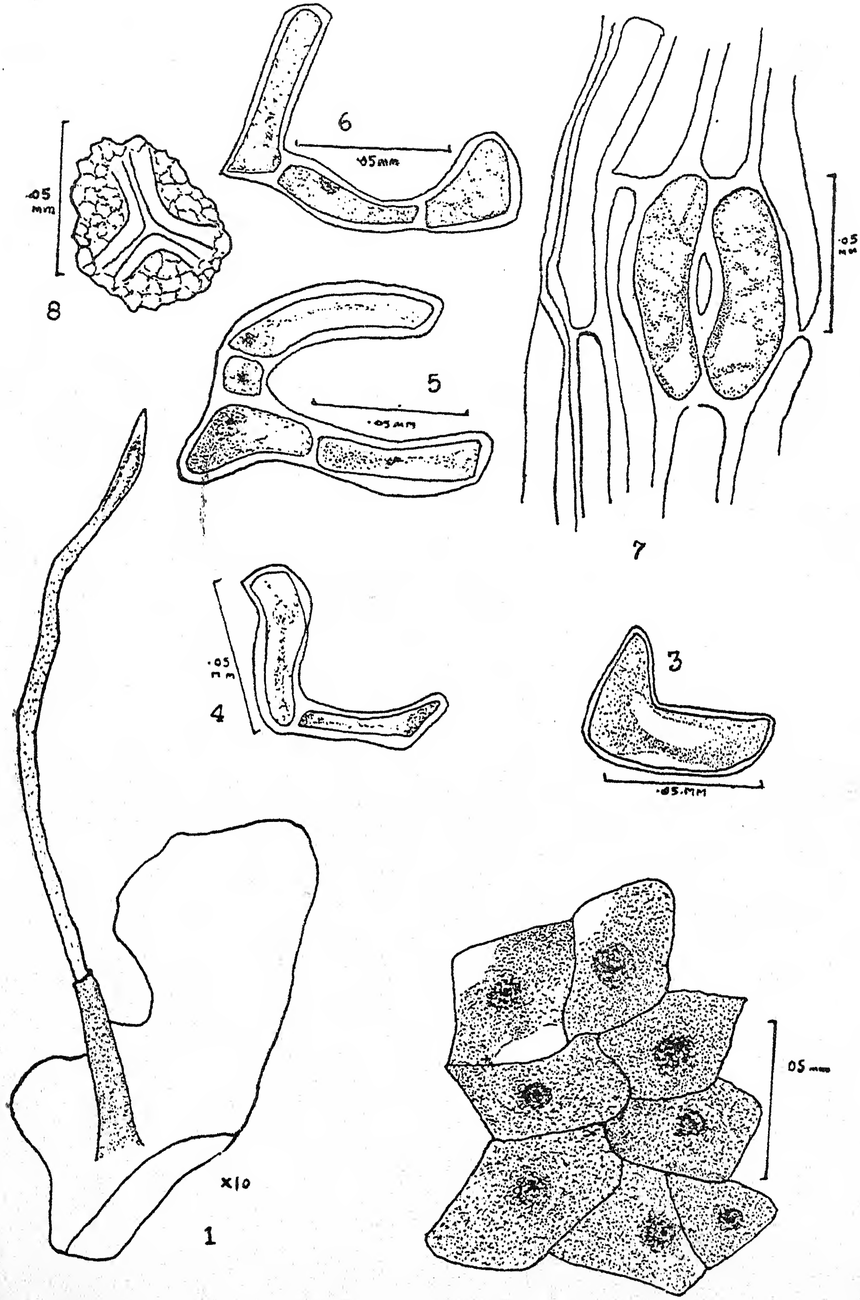
L. P. KHANNA

Biology Department, University of Rangoon

Received for publication on 17th February 1936

In 1915 Kashyap described from India two new species of the genus *Anthoceros* Linn., and in 1916 Stephani added twelve new Indian species. Of these latter, one name, *A. himalayensis*, had already been assigned by Kashyap to another species in 1915 and hence a distinctive name *A. Stephanii* is proposed. In 1917, Kashyap added another species to Indian Anthoceros. In 1923 Stephani further added four new species. Kashyap (1929) claimed that *A. Butleri* Stephani 1916 and *A. Longii* Stephani 1916 were probably synonymous with *A. erectus* Kashyap 1915. This appears to be erroneous, because *A. Butleri* Stephani 1916 and *A. Longii* Stephani 1915 differ from each other in many of the characters on which the classification of the genus is based—the colour of the spore, monoecious or dioecius habit, size of the plant and size of the involucre. The first species (*A. Butleri* Stephani 1916) differs from *A. erectus* Kashyap 1915 in being monoecious and having the spore pale coloured, the latter (*A. Longii* Stephani 1916) in being monoecious and having a smaller size of the involucre and a shorter capsule. Further Kashyap (1929) considered *A. Gollani* Stephani 1916 to be perhaps the same as *A. chambensis* Kashyap 1917, but the monoecious nature of the former together with the size of the involucre and the colour of the spore definitely dismisses his surmise. A comparative table of the characters of the so far known Indian species of *Anthoceros* is herewith provided.

For the material of the new species which forms the basis of this paper the writer is indebted to Professor T. K. Koshy, Maharaja's College of Science, Trivandrum, to whom he wishes to



Anthoceros Koshii sp. nov. (Figs. 1-8.)

1. Female plant. 2. Dorsal epidermal cells. 3—6. Pseudoelators. 7. Capsule wall showing stoma. 8. Spore.

express his thanks. Though the material was rather scanty it was in exceedingly good state of preservation. Thanks are also due to Prof. S. L. Ghose of Punjab University for the courtesy of providing co-type specimens of Kashyap's species from Kashyap's collection.

Of the known species of *Anthoceros* with dark spores the following are dioecious: *A. minutus* Mitten, *A. myriandroecius* Stephani 1916, *A. cucullatus* Stephani 1916, *A. lamellutus* Stephani 1916, *A. Weistii* Khanna 1932, *A. erectus* Kashyap 1915, *A. telaganus* Stephani 1916, *A. Parkinsonii* Khanna 1933, *A. chevalieri* Stephani 1916, *A. chambensis* Kashyap 1917, *A. Feridinandi* Stephani 1916, *A. Miyokeanus* Stephani 1916, *A. Faurianus* Stephani 1916. The present form differs from *A. minutus* Mitten by the longer size of the capsule and the bigger spores; from *A. myriandroecius* Stephani 1916, by the solid structure of thallus, the bigger involucre and the shorter capsule; from *A. cucullatus* Stephani 1916 by the shorter capsule and the bigger spores; from *A. lamellutus* 1916, by the shorter involucre and capsule and the bigger spores; *A. Weistii* Khanna 1932, by the smaller size of the plants, the shorter involucre and capsule; from *A. erectus* Kashyap 1916, by the solid structure of the thallus, the absence of large chambers in the thallus filled with mucilage and the shorter capsule with the bigger spores; from *A. telaganus* Stephani 1916, the bigger plant, the shorter involucre and capsule and the bigger spores; from *A. Parkinsonii* Khanna 1933, the longer involucre and the bigger spores; from *A. chevalieri* Stephani 1916 by the smaller size of the plant and the shorter capsule; *A. chambensis* Kashyap 1917, by the longer involucre, the shorter capsule and the bigger spores; from *A. Feridinandi* Stephani 1916, by the shorter involucre and capsule and the bigger spores; from *A. Miyokeanus* Stephani 1916 by the smaller size of the plants and the longer capsule; from *A. faurianus* Stephani 1916, by the shorter capsule and the bigger spores. It is, therefore, necessary to create a new species, for which I propose the name *Anthoceros Koshii* sp. nov.

DESCRIPTION

Anthoceros Koshii sp. nov.*

Dioecious. In pale green patches. Thallus 5-12 in diameter, depressed in centre, with margins slightly ascending and undulated; surface cells 0·025—0·04 x 0·045—0·07. Transverse section of middle of thallus 7—12 cells, solid. Involucre 2·8—3·6 long x 0·5—0·8 broad, cylinderical, slightly narrowed towards the apex. Capsule 12—15 long x 0·2—0·4 broad, stomata variable, averaging 0·075 x 0·05. Spores 0·055—0·065 dark papillate pseudoelators. Antheridia in groups of 2—8, scattered over the dorsal surface of the thallus.

Locality: Travancore: Peermade.

*All measurements in mm.

Comparative Table of the Characters

	Sexuality.	Plant Size.	Structure.
A. *alpinus* Stephani 1923 ..	Autoicous	5·0	Solid
A. *angustus* Stephani 1916 ..	Monoecious	20·0	Cavernous
A. *Butleri* Stephani 1916 ..	Monoecious	12·0	Cavernous
A. *cataractarum* Stephani 1916 ..	Monoecious	25·0	Solid
A. *chambensis* Kashyap 1917 ..	Dioecious	30·0	Cavernous
A. *erectus* Kashyap 1915 ..	Dioecious	10·0	Cavernous
A. *fuscus* Stephani 1916 ..	Monoecious	10·0	Cavernous
A. *Gollani* Stephani 1916 ..	Monoecious	10·0	Cavernous
A. *grosse-involucratus* Stephani 1923 ..	Autoicous	15·0	Cavernous
A. *himalayensis* Kashyap 1915 ..	Dioecious	†20·0	
A. *indicus* Stephani 1916 ..	Monoecious	15·0	Cavernous
A. *Jackii* Stephani 1923 ..	Autoicous	15·0	Solid
A. *Koshii* sp. nov. ..	Dioecious	10·0	Solid
A. *Longii* Stephani 1916 ..	Monoecious	5·0	Cavernous
A. *macrosporus* Stephani 1916 ..	Autoicous	20·0	Cavernous
A. *Meeboldii* Stephani 1916 ..	Autoicous	10·0	Solid
A. *notothyloides* Stephani 1923 ..	Autoicous	10·0	Cavernous
A. *Stephanii* Khanna ..	Monoecious	8·0	Cavernous
A. *subtilis* Stephani 1916 ..	Monoecious	5·0	Cavernous
A. *tenax* Stephani 1916 ..	Monoecious	20·0	Cavernous

D = Dark P = Pale; Op. = Opaque

of the Indian species of *Anthoceros*

Involucre.	Capsule.	Spores.	Distribution.
4·0	30·0	D. 0·054	India: Mussoorie
3·0	20·0	D. 0·036	Himalaya
5·0	20·0	P. 0·036	Himalaya
2·0	20·0	B. 0·036	Himalaya
2·5	25·0	Op. 0·04-·048	Chamba Valley; Punjab
5·0	30·0	B. 0·03-0·04	Outer and Kumaon Himalayas, Madras, Travancore
3·0	25·0	D. 0·045	Anam (India Orientalis)
4·0	30·0	P. 0·036	Himalaya
8·0	45·0	D. 0·036	Sikkim Himalaya
5·0	30·0	Y. 0·025	Common throughout the outer and the Kumaon Himalayas. Rare y in Lahore
3·0	20·0	D. 0·036	India Orientalis, Mysore
3·0	30·0	Y. 0·036	Himalaya: Mussoorie
2·8-3·6	12-15	D. 0·55-0·65	S. India: Peermade
2·0	20·0	B. 0·045	Himalaya: Simla
4·0	40·0	B. 0·054	India Orientalis : Bhor Ghat
2·0	30·0	B. 0·045	India Orientalis : Travancore
3·0	15·0	B. 0·036	India
3·0	30·0	D. 0·036	Himalaya
2·0	12·0	D. 0·036	India: Mangalore
4·0	30·0	P 0·036	Himalaya

B. = Black; Y. = Yellow.

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EXTRA-FLORAL NECTARIES IN *TECOMA CAPENSIS* LINDL.

BY

P. PARIJA

AND

K. SAMAL

Ravenshaw College, Cuttack

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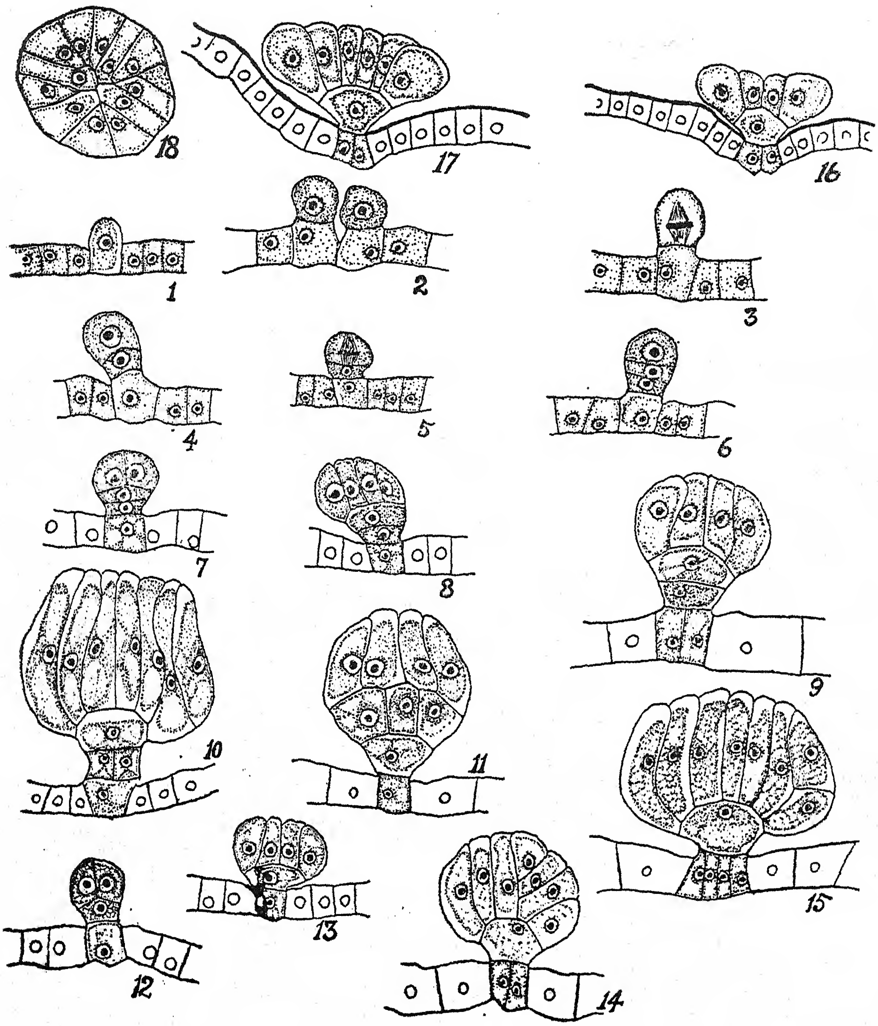
Introduction

Besides the anatomical peculiarities, the family Bignoniaceae possesses, various other features uncommon in allied families. Solereder (1908, p. 601) mentions epidermal out-growths in various genera of this family, which may be unicellular or multicellular trichomes, branched or unbranched. In addition to the trichomes, multicellular glands, and patelliform glands are abundantly found in many parts of the plant. In various plants examined by him and by others, the patelliform glands were found to excrete sugary juice. Rao (1926, p. 113) described such extra-floral nectaries in *Spathodea stipulata* Wall besides the epidermal multicellular glands. He found these nectaries abundant on the abaxial side of all the floral and foliar parts, scattered or forming local aggregations and they excreted both cane-sugar and grape-sugar. The glands on the inner side of the calyx were found by Haberlandt (1914, p. 501) in *Spathodea campanulata* and by Rao (1926, p. 113) in *Spathodea stipulata* Wall to function as water excreting organs. Morini (Solereder, 1908, p. 601) observed such glands in *Bignonia grandiflora* and *Tecoma radicans*.

In the present work, the extra-floral nectaries in *Tecoma capensis* Lindl. were studied and the results are recorded.

Distribution of Glands

(i) *Glandular Hairs*—Multicellular glandular epidermal outgrowths occur in abundance in all aerial parts of the plant, including both vegetative and reproductive and are uniformly distributed; they have, however, different anatomical structures. On the morphologically lower side of the calyx, corolla and the leaves, there occur certain glandular hairs (Figs. 16-18) which look different from those distributed on the morphologically upper side of these organs and the stems (Figs. 1-15).



Figs. 1—18. *Tecoma capensis* Lindl.

Figs. 1-11. Stages in the development of the glandular hairs on the morphologically upper side of the floral and foliar parts. X 460. Figs. 12-15. A second series of development of similar glands on the same side of the floral and foliar parts. X 460. Figs. 16-17. Fully developed stages of the glandular hairs on the morphologically lower side of the floral and the foliar parts. X 460. Fig. 18. Surface view of a gland, the side view of which is represented in Fig. 17. X 460.

(ii) *Extra-floral Nectaries.*—Besides these glandular hairs, there occur patelliform glands, the so called extra-floral nectaries in certain localised parts of the calyx, corolla and the petiole. In both calyx and corolla, they occur always on the dorsal surface of those sepals and petals which are away from the mother axis. Their distribution on the sepal is different from that on the petal; in the sepal, their position is marginal along the margins of the lobes of the gamosepalous calyx and in the petals, their position is central, along both the sides of the midrib (Fig. 23). In the petioles, they are restricted to the apex only, just below the lamina and along both the ridges of the petiolar groove.

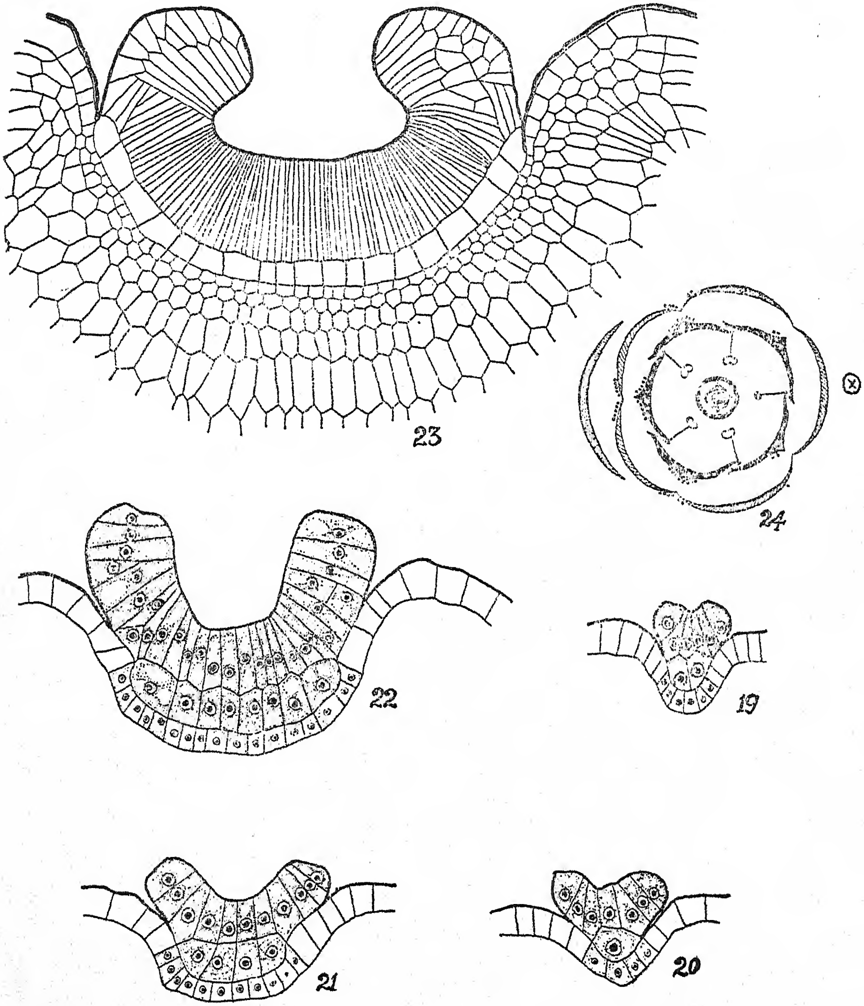
Structure and Development of the Glands

Glandular Hairs.—Progressive development of these hairs on the morphologically upper side of the vegetative and floral parts have been shown in figures 1-11 and figures 12-15 in two different series. Detailed study of these hairs shows that there are two types of hairs belonging to two different developmental series. All of them are epidermal outgrowths and they begin their early development in the same way. The epidermal cell at regular intervals enlarges in dimension with dense cytoplasm and large nucleus; it devides into two cells (Fig. 2), the apical cell by two further divisions forms a row of three cells (Fig. 6), or by a single transverse divison forms a two-celled row (Fig. 12). Further division takes place mostly in the apical cell by vertical walls (Figs. 7-9). Sometimes the basal and the middle cells divide (Figs. 10 and 11). The epidermal cell supporting the glandular hair may divide by vertical walls. The second series starts from the two celled-row by the division of the apical cell by vertical walls. The stalk cell never divides in this series and the stalk is always represented by a single cell but the epidermal cell supporting the glandular hair is seen to divide many times (Fig. 15). The apical cell always divides first of all by vertical walls, but later on, these resultant cells may divide by transverse walls also (Figs. 14 and 15).

Development of the glandular hairs on the morphologically lower side is exactly similar to that of the glands belonging to the series of the two-celled row. Here the stalk is composed of a single cell only and the apical cell divides always by vertical walls and never transversely. The epidermal cell just below the gland divides very often (Figs. 16 and 17).

Extra-floral nectaries.—They are found in pits formed by the undulation of the epidermis. They form cup-like structures, composed of club shaped cells arranged vertically on a sub-hymenial layer lining the epidermis (Fig. 23). The sub-hymenial layer consists of a single layer of cells lying outside the epidermis and supporting the patelliform glands above. All these glandular cells are not of the same size, those supported by the uniseriate stalk cells forming the sub-hymenial layer, are

much elongated and are mostly vertical in their arrangement whereas those glandular cells towards the margins are not so much elongated and they are comparatively much broader. These marginal cells are unsupported by the stalk and are arranged almost transversely (Fig. 23). The epidermal layer supporting the stalk is composed of comparatively smaller cells but with denser cytoplasm (Fig. 22).



Figs. 19—24. *Tecoma capensis* Lindl.

Figs. 19-22. Stages in the development of the nectar excreting patelliform glands on the calyx. X 460. Fig. 23, Fully developed stage of an extra-floral nectary. X 200. Fig. 24. Floral diagram of *Tecoma capensis* Lindl. showing the locotion of the extra-floral nectaries.

Such a nectary in its early stages of development looks much similar to a glandular hair developed on the dorsal side of the organs (Compare fig. 16 and fig. 20). In both the cases the stalk consists of a single cell, but later in the case of the nectaries, it divides gradually into a number of cells simultaneously with the division of the glandular cells above. Thus these nectaries like the glandular hairs are epidermal outgrowths which differentiate very soon into much complicated structures. Development of these glandular hairs and the so-called extra-floral nectaries suggest the origin of the latter from the former, the greater complexity of the latter being due to the tendency to increase the area of secretion. Origin and full development of these glandular hairs and nectaries have been noticed much before the differentiation of the sporogenous tissue in the ovules and in the anther. *Tecoma capensis* Lindl. possesses true nectaries also but their development is fundamentally different from these extra-floral ones; they are composed of cortical tissue and are developed internal to the epidermis.

Nature of Secretion

Glandular Hairs.—The nature of the glandular hair, their denser cytoplasm and comparatively bigger nucleus suggest their secreting function. Washings with distilled water from the leaf surface, where the patelliform glands are absent, give no test for sugar or any salt and therefore, if they actually secrete anything, it must be pure water and they must be doing the work of hydathodes only, as Haberlandt (1914, p. 501) has suggested.

Extra-floral nectaries.—Washings of the flowers with distilled water give distinct tests for glucose and cane-sugar. Such glands on the calyx give tests for the sugars many days before anthesis and black ants in large numbers are found visiting the flowers both day and night. Nectaries are present only on the outer surface of the calyx and corolla away from the mother axis, so that when the mother axis remains vertically up, the nectaries face vertically down by the bending of the pedicel. If the mother axis of the inflorescence happens to lie differently other than vertical, the pedicels of the flowers twist through different angles even up to 180° to keep the nectaries vertically down. The petioles also show different orientations to keep its nectaries vertically down. This sort of apparently downward position of the nectaries is most probably for their protection against rain and the sun. This is certainly a good protection against rain, because the ants are found gathering honey even after a heavy shower. Petioles in the shade do not show bending for the protection of the honey in their nectaries against drying up in the sun. This suggests that it is not gravity but light which brings about the orientation of the petioles and the flowers for the protection of the honey in their patelliform glands.

Discussion

Origin of the extra-floral nectaries.—Haberlandt (1914, p. 501) and Rao(1926, p. 113) think that the origin of these nectaries is from the glandular hairs. A study of the progressive development of the different kinds of glandular hairs and the extra-floral nectaries confirms this view.

Function of the nectaries.—It is difficult to suggest anything regarding on the function of such patelliform glands. Haberlandt (1914, p. 501) suggested that such glands are further additions to the secretory function of the normal floral nectaries which are not in these plants at a high state of differentiation. This suggestion is rather ambiguous, because the floral nectaries secrete relatively so little of honey that its profuse secretion from these glands keeps away the visitors from the true nectaries and thus hindering cross-pollination which would have been otherwise possible. Another interesting feature is that the nectar is secreted from the very early stage of the buds and much before anthesis. It seems that these patelliform glands keep away the unwelcome ants from visiting the flowers, and thereby probably favour self-pollination.

Summary

1. Glandular hairs are found in *Tecoma capensis* Lindl. in floral and foliar parts, distributed uniformly. They are of three different types.
2. Patelliform glands are present on the dorsal surface of the calyx and corolla and on the ventral surface of the petioles.
3. Patelliform or the so-called extra-floral nectaries excrete glucose and cane-sugar and the glandular hairs excrete water.
4. All these different types of water excreting or nectar excreting glands are purely the modifications of the outgrowth of the epidermal cells.
5. A study of the gradual development of all kinds of epidermal outgrowths suggests the origin of the nectar excreting patelliform glands from the glandular hairs.

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* SOME ECOLOGICAL ASPECTS OF THE UPPER GANGETIC FLORA

BY

S. C. VARMA, M. Sc. (LUCKNOW), PH. D. (LONDON)

Demonstrator in Botany, Lucknow University

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Contents

Introduction

The Upper Gangetic Plain is a vast expanse of flat country. It is mostly under cultivation but grass covered waste land or thorny scrub are found in certain areas. The forests occur at the foot of the Himalayas which forms the northern boundary of this great plain. The soil is all alluvial, deposited in recent times. Its structure ranges from sand through various mixtures of sand and clay to fine clay. The older alluvium often contains deposits of calcium carbonate in irregular nodules, locally called "Kankar."

The nearest large body of water is the Bay of Bengal which is more than 500 miles away. The climate, therefore, is distinctly continental and shows a large range of temperature between summer and winter. Owing to monsoon conditions the year is divided into three seasons, *viz.*,

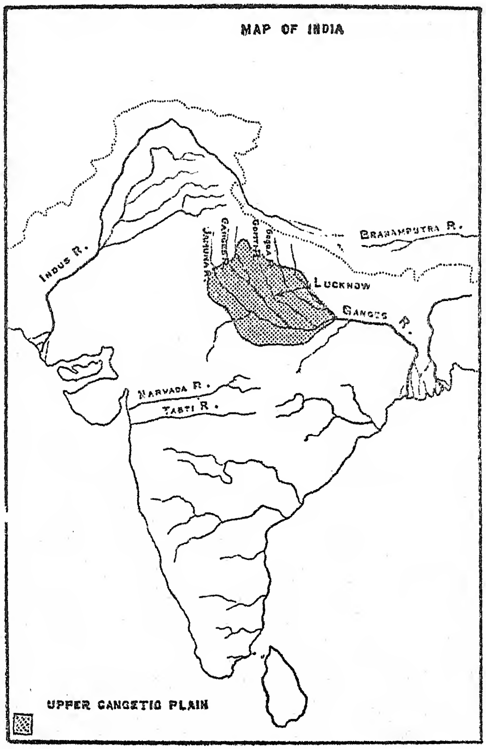
(i) the Rainy season from the last week of June to October,

(ii) the Winter season from October to February and

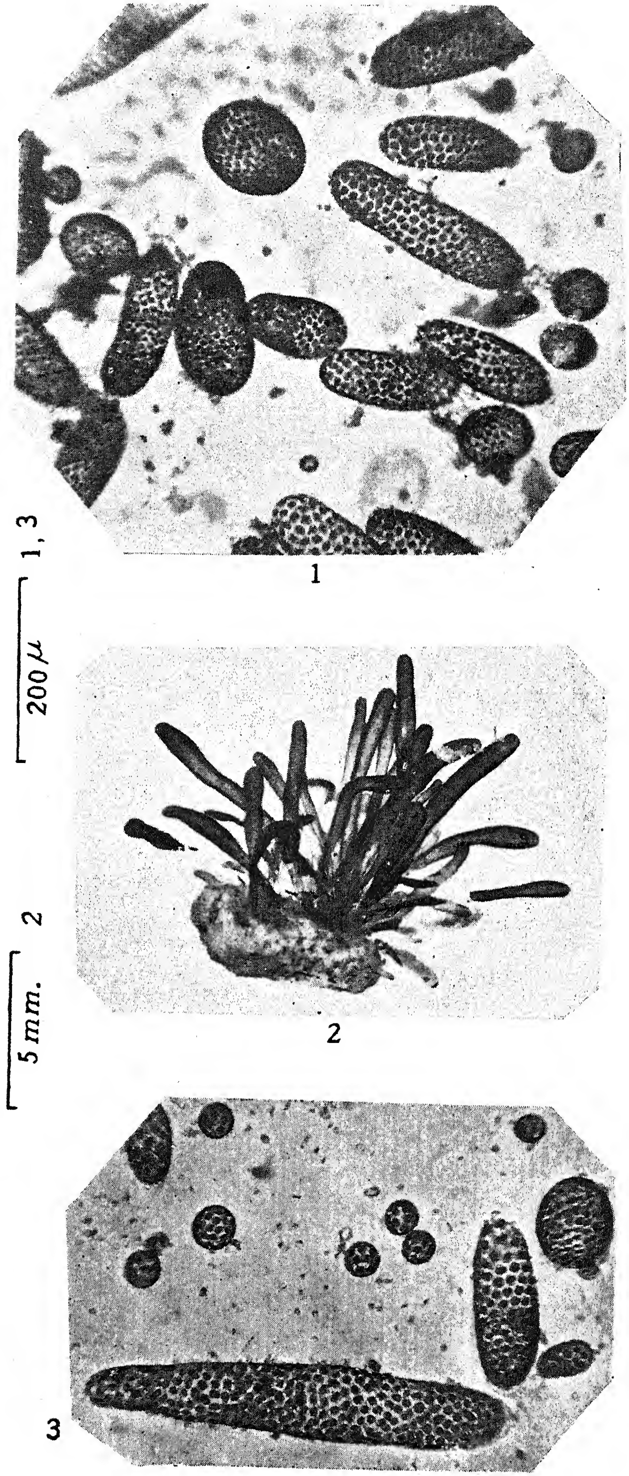
(iii) the Summer season from March to the third week of June.

* A part of this paper under the heading "On some aspects of the Ecology of Plants of the Upper Gangetic Plain" was read before the Botanical Society, University College, London, in March 1934.

Lucknow, 26·52 N latitude and 80·58 E longitude, is situated on the right and south bank of the Gomti River, a northern tributary of the Ganges. The mean height is about 365 feet above sea level.



Thos. Anderson (1) was the first to give a systematic account of the Lucknow flora and he also drew attention, like several others (Hooker and Thompson (4)), to the marked periodicity of the climate of this region. They also observed that the Upper Gangetic Plain was mostly under cultivation and the forests were confined to the foot of the Himalayas in the north. The uncultivated parts were covered with "bush jungles". Schimper (9) classified the xerophilous shrubs and trees that are found on the waste-land as "thorn-scrub". Dudgeon (3) states that the present vegetation is in the dry meadow stage and would develop into a deciduous monsoon forest if left undisturbed by man. Saxton (8) has tried to group the plants of different seasons into a number of Synusia (Gam's). A detailed investigation of the ecology of this region has not been made so far and this paper is a preliminary attempt to correlate the various edaphic and



Characiosiphon rivularis Iyengar

FIGS. 1, 3. Photomicrographs of germlings growing attached to slides kept in the culture dishes, showing various stages of development.

climatic factors with the nature and growth of plants in the vicinity of Lucknow.

The work embodied in this paper was carried out in the Botany Department of Lucknow University during 1931-32. It was started at the suggestion of the late Dr. S. K. Mukerjee, D.Sc. (London), F.L.S. for whose inspiration and constant guidance I am deeply grateful. I am also very thankful to Professor B. Sahni, F.R.S., for his kind help and permission to consult the manuscripts of the late Dr. S. K. Mukerjee from which some references to literature were of great use. My thanks are also due to the Librarian, India House, London, for permitting me the use of the meteorological tables. I am very much indebted to Professor E. J. Salisbury, F.R.S., for much helpful advice and criticisms and for kindly going through the manuscript. The map has been drawn by Mr. V. S. Sharma, the laboratory assistant, to whom I am very thankful.

Methods

The methods of investigation were those suggested by Clements (2). Ten permanent quadrats of 1 square metre each were laid out in different but similar localities near Lucknow. The number and kind of plants were recorded on monthly, sometimes fortnightly, visits. On every visit to the quadrats, air and soil temperatures, light intensity and wind velocity were recorded. At the same time a weighed quantity of the soil from different depths in these quadrats was brought to the laboratory. This soil was heated to 105°C until it attained constant weight and the water content was calculated from the loss in weight.

The hydrogen-ion-concentration of the soils was determined by the colorimetric method with British Drug House reagents and buffer standards. The total carbonate content was determined with the help of Collin's Calcimetre. The Diphenylamine test was employed in order to find out roughly the amount of nitrates present in the soil. The soil was treated with toluene before it was brought to the laboratory in order to eliminate any error caused by the denitrifying bacteria. The loss on ignition was determined by finding out the loss of weight on heating the soil till it attained constant weight. Each of these determinations were carried out on the soils collected on every visit to the quadrats.

Discussion of Results

The localities in which these quadrats were situated were all similar and each quadrat acted as a check to the other. The following conclusions are based on the results obtained from all the quadrats taken together. It has been pointed out that there are

three seasons in a year and in the following description the various aspects of the ecology are dealt with from one season to the other beginning with the rainy season.

1. *The Rainy Season* :—The rainy season extended, as it usually does, from the last week of June to the middle of October in the year investigated. The maximum temperature varied from 93°F. in July to 88°F. in October, and minimum temperature varied from 80°F. in July to 70°F. in October. The range between maximum and minimum temperature during this season was 11°F. in August and 12°F. in September and this range gradually increased until in February it was 30°F. as shown in Table I.

TABLE I

Mean temperature in degrees Fahrenheit

(From Meteorological Tables)

—	June 1931	July 1931	August 1931	September 1931	October 1931	November 1931	December 1931	January 1932	February 1932	March 1932	April 1932	May 1932
Maximum Temperature ..	106·8	93	91·4	90·4	88·6	83·6	77·0	78·5	80·0	92·7	101·6	106·3
Minimum Temperature ..	83	79·5	80·0	77·7	70·3	55·9	50·5	49·6	50·3	62·2	71·3	78·2
Range ..	23·8	13·5	11·4	12·7	18·3	27·7	26·5	28·9	29·7	30·5	30·3	28·3

The total rainfall of the year was 38·5 inches of which 36·57 inches, i.e., 94·8% of the total rainfall, fell during the rainy season, and out of 43·4 rainy days 40 were in this season (Table II). This will show that most of the rain fell during these four months. It often fell in torrents with intervals of bright periods. Prevalent high temperature minimised to a great extent the beneficial effect of the rainfall upon the soil. An appreciable amount of the surface soil, where unprotected, was washed off to low-lying areas owing to torrential rain. In such areas the salts which the rain water had dissolved during its course accumulate. The water content of the surface soil after the first rainfall of the season was found to be much higher than at lower levels (Table III). This is explained by the fact that the water rapidly flowed off after a heavy fall of rain and there was not enough time allowed for the water to percolate to a lower substratum. Later on in the season the water reached lower levels with the consequent rise in the ground water level.

TABLE II

(From Meteorological Tables)

—	June 1931	July 1931	August 1931	September 1931	October 1931	November 1931	December 1931	January 1932	February 1932	March 1932	April 1932	May 1932
Actual Rainfall	1·29	10·71″	9·63″	12·5″	3·73″	0	0	0	0·26″	0·08″	0·06″	0·24″
Per cent Rainfall	3·3	27·8	25·0	32·4	9·6	0	0	0	0·67	0·20	0·15	0·52
Actual Rainy days ..	1·9	13·4	12·9	10·1	3·6	0	0	0	0·6	0·2	0·2	0·5
Per cent Rainy days ..	4·3	30·8	29·7	23·2	8·2	0	0	0	1·3	0·46	0·46	1·1

The 1st week of June was the height of summer, while the 4th week of June marked the beginning of the rainy season.

TABLE III

Water content of the soil

	Quadrat I			Quadrat II			Quadrat IV		Quadrat VI			Quadrat VII		Quadrat X		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st week .. June	0·30	0·38	0·64	1·5	1·3	1·9	0·08	0·1	0·3	0·38	0·36	0·1	0·22	0·06	0·36	0·14
4th week .. June	6·5	1·9	1·5	5·8	2·5	1·9	15·9	2·04	8·5	6·1	2·2	17·09	5·4	7·7	6·8	0·95
2nd week .. July	0·67	3·08	2·6	0·59	2·7	5·2	0·85	0·48	0·79	2·9	3·6	1·6	1·2	0·81	6·01	6·4
4th week .. July	5·5	7·9	7·8	5·1	9·7	11·0	19·8	10·7	4·4	6·6	6·8	18·0	8·0	4·4	5·1	6·8
2nd week .. August	17·1	12·5	12·1	18·3	19·2	21·5	18·1	9·6	15·3	15·3	14·9	22·3	11·5	12·9	12·3	11·9
4th week .. August	13·1	12·7	7·1	11·03	16·0	13·5	7·4	7·7	6·6	8·2	8·4	7·1	8·4	4·7	8·2	9·3

Owing to hot sun and intense evaporation a severe drought was produced during the intervals of bright periods that occurred between the rainy days. These bright periods were sometimes sufficiently prolonged as in the June and July of 1932. First rain fell on the 21st June 1932 and after a couple of inches fall the rain stopped for over three weeks before the second rain fell on 20th July 1932. Large numbers of seedlings were killed as a result of the drought.

From Table IV it will be seen that between the first and second rain there was an interval of about three weeks and the number of seedlings that germinated after the first rainfall gradually dwindled down to a small figure before the second rain started. Table IV also shows that out of 247 seedlings in Quadrat number 1, that germinated after the first rain, only 10 could survive; but in the case of Quadrat 6 out of 588 seedlings 70 were able to withstand the adverse conditions. The death of a certain percentage of these seedlings may reasonably be ascribed to other factors than drought, but on the whole it seems that the majority of the seedlings were killed through adverse physical factors brought about by the absence of rain.

It may, however, be emphasized that the seedlings of different plants differed in their capacity to withstand adverse conditions. Thus, out of 203 seedlings of *Rungia parviflora* var. *pectinata* that germinated after the first rain only 4 were able to survive the drought, while in the case of the seedlings of *Commelina benghalensis* out of 14 seedlings that germinated four were able to survive. Again in Quadrat 6, 440 seedlings of *Vandellia crustacea* germinated but none could survive, while out of 67 seedlings of *Euphorbia hirta* 45 were able to withstand the adverse conditions in the same quadrat. The differing capacities of the seedlings of different plants to withstand adverse conditions will determine to a great extent the nature of the resulting plant community.

It will again be noticed from Table IV that just after the second rainfall (22-7-32) a new group of seeds that lay dormant during the period of drought germinated. The Table shows that just after the second rainfall the number of seedlings in Quadrat 1 increased from 10 to 177, in Quadrat 6 the number of seedlings increased from 70 to 232. The intermittent germination of seeds under such weather provided the plants with a new lease of life and enhanced their chances of survival. Salisbury (7) has also drawn attention to the importance of intermittent germination in the survival of certain plants. At the incidence of severe frost he has noticed that species with discontinuous germination survived while those with simultaneous germination were eliminated.

The total nitrate content of the surface soil was higher at the beginning of June when summer was at its height than in any other season. From Table V will be seen that the diphenylamine test

TABLE IV

Date.	Rainfall in Inches. (From Meteorological Tables)	Per cent Humidity (From Meteorological Tables)	Number of Seedlings in Quadrat I.	Number of Seedlings in Quadrat VI.	Number of Seedlings in Quadrat II.
20th June 1932 ..	0	21	..	..	..
21st ,, ,, ..	0·5	57	First	day of	rain
22nd ,, ,, ..	1·15	88	0	0	0
23rd ,, ,, ..	0·15	80	0	98	27
24th ,, ,, ..	0·20	87	0	143	45
25th ,, ,, ..	..	..	247	582	49
26th ,, ,, ..	..	..	249	588	49
27th ,, ,, ..	0	47	..	..	..
28th ,, ,, ..	0	33	244	575	48
29th ,, ,, ..	Showers	29	240	573	47
30th ,, ,, ..	Showers	76	214	472	44
1st July 1932 ..	Showers	44	203	441	46
2nd ,, ,, ..	0	58	200	429	45
3rd ,, ,, ..	0·25	..	..	..	..
4th ,, ,, ..	0	77	183	416	44
5th ,, ,, ..	0·15	57	161	398	44
6th ,, ,, ..	0	60	148	390	40
7th ,, ,, ..	0	65	143	363	36
8th ,, ,, ..	0·3	84	125	340	30
9th ,, ,, ..	Showers	48	128	322	26
10th ,, ,, ..	..	..	..	..	..
11th ,, ,, ..	0	52	..	..	..
12th ,, ,, ..	0	45	83	121	17
13th ,, ,, ..	Showers	54	28	101	19
14th ,, ,, ..	Showers	49	28	90	17

TABLE IV—(*continued*).

Date.	Rainfall in Inches. (From Meteorological Tables).	Per cent Humidity. (From Meteorological Tables).	Number of Seedlings in Quadrat I.	Number of Seedlings in Quadrat VI.	Number of Seedlings in Quadrat II.
15th July 1932 ..	..	37	23	80	18
16th ,, ,, ..	..	..	17	78	18
17th ,, ,, ..	Showers	..	..	..	..
18th ,, ,, ..	0	46	12	73	18
19th ,, ,, ..	0	38	11	70	18
20th ,, ,, ..	1·43	55	10	70	18
21st ,, ,, ..	1·60	71	10	73	18
22nd ,, ,, ..	0·80	53	42	77	18
23rd ,, ,, ..	0·12	59	177	232	18
24th ,, ,, ..	..	..	..	..	..
25th ,, ,, ..	0	45	168	252	22
26th ,, ,, ..	Showers	54	141	248	22
27th ,, ,, ..	Showers	59	121	246	22
28th ,, ,, ..	0·83	59	..	..	..
29th ,, ,, ..	0·65	78	131	248	25
30th ,, ,, ..	0·90	74	132	253	25
31st ,, ,, ..	..	..	..	..	..
1st August 1932 ..	0·72	64	142	296	25
2nd ,, ,, ..	0·30	82	144	278	28
3rd ,, ,, ..	0·12	87	..	..	..
4th ,, ,, ..	0·30	87	189	321	39
5th ,, ,, ..	Showers	82	189	323	42
6th ,, ,, ..	1·10	91	..	..	..
7th ,, ,, ..	..	..	..	..	..
8th ,, ,, ..	0·29	70	..	..	..

TABLE IV—*(continued)*.

Date.	Rainfall in Inches. (From Meteorological Tables.)	Per cent Humidity (From Meteorological Tables.)	Number of Seedlings in Quadrat I.	Number of Seedlings in Quadrat VI.	Number of Seedlings in Quadrat II.
9th August 1932 ..	0·24	69	..	..	..
10th ,, ,, ..	0·12	67	..	..	..
11th ,, ,, ..	0·50	76	..	..	..
12th ,, ,, ..	0·30	87	..	..	..
13th ,, ,, ..	Showers	72	..	..	..
14th ,, ,, ..	..	..	177	508	37
15th ,, ,, ..	0·12	79	..	..	..
16th ,, ,, ..	..	..	..	..	..
17th ,, ,, ..	1·14	78	..	..	..
18th ,, ,, ..	0	58	180	585	35
19th ,, ,, ..	0	58	..	..	..
20th ,, ,, ..	0	63	..	..	..
21st ,, ,, ..	..	..	..	..	..
22nd ,, ,, ..	2·3	60	..	..	..
23rd ,, ,, ..	Showers	54	..	..	..
24th ,, ,, ..	0	54	..	..	..
25th ,, ,, ..	..	..	..	..	..
26th ,, ,, ..	0	46	183	551	35
27th ,, ,, ..	0	39	..	..	..
28th ,, ,, ..	..	..	..	..	..
29th ,, ,, ..	0	42	..	..	..
30th ,, ,, ..	0	40	..	..	..
31st ,, ,, ..	0	34	171	347	52

showed a normally high quantity of nitrates in the surface soil. The amount of nitrates, however, suddenly fell with the depth. After

rainfall the nitrates were washed down to the lower layers of the soil (Table V). This amount of the nitrates was presumably lost in the deeper layers of the soil where it was available only to the deep-rooted plants.

The carbonate content of the soil in the plots studied (Table VI) did not show any appreciable variation from season to season, but, as pointed out before, large quantities of calcium carbonate are found deposited in old alluvium as irregular nodules. Where these nodules occur the cultivation becomes uneconomical and it is sooner or later given up. These nodules make good road surfaces for which purpose these are constantly removed.

If higher values of hydrogen-ion-concentration (pH) give any clue as to the high content of salts, then it will be evident from Table VII that there was higher concentration of salts on the surface soil during the hot season than in the rainy season. After rainfall the pH value fell immediately bringing the soil reaction more or less to neutral point.

The amount of humus as judged by the loss on ignition (Table VIII) was low. This low value is probably due to its rapid decomposition during hot weather, as is borne out by the fact that the total humus content of the soil was lower in the summer season than in the winter or rainy seasons.

In summing up the several factors it will be found that during the rainy season with the advent of monsoons, the water content of the soil increased, the temperature of the air as well as of the soil decreased considerably as compared with what it was during the summer. The nitrates and other salts were washed to lower substrata. There was a tendency towards the decrease of the total carbonates in the soil, and increase of organic matter on the surface of the soil. The reaction of the soil was less alkaline and on the whole the climatic and edaphic factors were very suitable for plant life.

The trees and shrubs, phanerophytes in Raunkiaer's terms, were either confined to waste lands, or to the edges of cultivated fields, road sides and gardens. The ground was covered with herbaceous plants at this time of the year. Different species were dominant at different places and in the quadrats studied it was found that in Quadrat 1 *Rungia parviflora* var. *pectinata* was dominant, grasses (*Andropogon* sp. and *Cynodon* sp.) were occupying a subordinate position. In Quadrat 2 grasses were dominant and yet in another quadrat *Sida veronicaefolia* was dominant. Grasses on the whole formed the characteristic feature of the physiognomy. It will be seen from Table IX that in the rainy season, owing to favourable conditions for plant growth, the largest number of plants were recorded per metre square area. The grasses were not included in the counts, with their inclusion the total number of plants per metre square area would have been more than twice as many.

TABLE V

Nitrate Content of the soil (Diphenylamine test.)

—	Quadrat I			Quadrat II			Quadrat IV		Quadrat VI			Quadrat VII		Quadrat X		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June ..	+++	++	+	++++	+++	++	++	++	+++ +++	+++	++	+++ +++	++	+++ +++	++	+
4th Week June ..	++	++	+	+++	++	+	++	+	±	++	+	++++	+++	+	++++	+
2nd Week July ..	++	++	+++	+++	++	++	++	+	++	±	+	+	+	++	++	++++
4th Week July ..	++++	+	+	+++	+	+	+	+	+	±	±	+	+	++++	+	+++
2nd Week August ..	++	+	++	+	±	+	±	±	±	±	++	±	+	±	+	+
4th Week August ..	++	+	++	++	+	+	+	+	+	+	+	±	+	+	+	+

TABLE VI

Total Carbonates

—	Quadrat I			Quadrat II			Quadrat IV		Quadrat VI			Quadrat VII		Quadrat X		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June	1·1	1·5	1·09	3·57	5·4	4·3	0	0	0·12	0·12	0·08	0·21	0·12	0·21	0·12	0·54
4th Week June	1·4	1·9	1·9	4·09	5·4	6·13	0	0	0·36	0·4	0	0·45	0	0·36	0·36	0·81
2nd Week July	1·3	2·0	0·9	3·2	4·5	4·3	0	0	0·204	0·16	0	0·2	0	0·4	0·57	3·2
4th Week July	1·6	1·7	1·8	4·3	4·5	4·6	0	0	0·38	0·22	0	0·22	0	0·36	0·28	0·13
2nd Week August	1·21	1·38	0·69	4·2	5·3	6·5	0	0	0	0	0·09	0·28	0·04	0·2	0·2	0·24
4th Week August	1·38	1·6	0·7	2·2	5·1	4·3	0	0	0.08	0	0·06	0·36	0·04	0·28	0·4	0·28
Average	1·3	1·7	1·2	3·6	5·0	5·0	0	0	0·19	0·15	0·08	0·28	0·03	0·2	0·32	0·86

TABLE VII

Hydrogen-ion-Concentration (pH) of the soil

—	Quadrat I.			Quadrat II.			Quadrat IV.		Quadrat VI.			Quadrat VII.		Quadrat X.		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June	7·3	7·6	7·3	7·4	7·4	7·6	7·1	7·0	7·1	7·2	7·3	7·1	7·1	7·3	7·3	7·3
4th Week June	7·0	7·2	7·2	7·2	7·3	7·4	7·1	6·7	6·8	7·2	7·1	6·8	6·6	7·1	7·2	7.2
2nd Week July	7·0	7·3	7·2	7·2	7·2	7·2	6·9	6·4	7·0	7·2	7·0	7·0	6·6	7·2	7·2	7·2
4th Week July	7·0	7·2	7·0	7·2	7·1	7·3	6·5	6·6	7·0	7·0	6·8	6·8	6·8	7·2	7·1	7·2
2nd Week August	7·2	7·2	7·2	7·5	7·4	6·9	6·9	7·0	7·1	7·0	7·1	7·2	7·0	7·1	7·2	7·2
4th Week August	6·9	7·2	7·2	7·3	7·4	7·2	7·2	6·9	7·0	7·1	7·1	7·4	7·2	7·2	7·2	7·2
Average	7·0	7·3	7·2	7·3	7·3	7·2	6·9	6·7	7·0	7·1	7·0	7·0	7·0	7·2	7·2	7·2

TABLE VIII

Loss on ignition of the soil

	Quadrat I.			Quadrat II.			Quadrat IV.		Quadrat VI.			Quadrat VII.		Quadrat X.		
	0″	6″	12″	0″	6″	12″	0″	6″	0″	6″	12″	0″	6″	0″	6″	12″
1932																
1st Week June	4·3	3·4	2·7	5·7	5·4	4·4	5·08	2·8	2·7	3·3	1·8	5·6	1·4	2·8	1·08	2·6
4th Week June	5·5	3·4	3·1	4·4	4·2	5·5	7·01	1·9	3·4	2·9	2·5	5·5	2·05	2·5	2·8	2·3
2nd Week July	5·6	4·04	2·6	4·8	4·6	5·2	3·3	2·3	3·06	·95	2·4	6·04	2·1	3·6	3·3	3·6
4th Week July	6·4	3·5	3·59	4·7	4·0	2·6	4·51	2·17	3·06	3·7	3·3	5·5	·68	2·4	2·2	1·4
2nd Week August	4·0	2·6	2·9	5·3	4·1	1·7	4·05	1·6	2·9	2·1	3·4	6·4	3·3	2·4	2·7	1·21
4th Week August	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Average	5·1	3·4	2·9	5·0	4·4	3·9	4·8	2·1	3·0	2·6	2·7	5·8	2·3	2·7	2·4	2·2

Most of the herbaceous plants were therophytes, *i.e.*, they passed the unfavourable period in the seed stage. In certain cases the life cycle was completed very quickly, and specimens of *Bonnaya bracheata* and *Vandellia crustacea* were found to bear flowers, while the cotyledons were still green. It was very difficult to say in such cases the age up to which the seedling stage persisted. The hot dry season was tided over by these plants in the seed stage and just after the first rains, when the conditions for germination became favourable, the first to appear were grasses. The germination of other seeds was delayed by a day, but there was prolific outgrowth of seelings and the whole ground was overcrowded with herbaceous plants within a few days after the first rain. It has been pointed out previously that during this time when rain stopped for a few days the surface soil became dry, causing the death of many of the seedlings. If the seeds of such plants germinated intermittently their chances of survival were enhanced in these sudden changes of climate.

The first appearance even of grasses, which are otherwise known to spread vegetatively during the growing period, was through the germination of seeds. Other plants also while they tided over the summer conditions in the seed stage spread vegetatively during the growing season. Such a case was found with *Rungia parviflora* var. *pectinata* and it was true of a number of other plants as well.

During the rainy season water accumulates in depressions and a few hydrophytes make their appearance, but these investigations were confined only to the land plants.

The characteristic vegetation during this season was hygrophilous on the whole and it was in the rainy season that the tropical aspect of the flora as well as its composition appeared more clearly.

2. *The Winter Season*:—The winter season extended, as it does, from October to the end of February. It was followed by a short-lived spring. During this season the temperature was lower than in the rainy season. The mean maximum temperature was 88°F. in October, 77°F. in December and 80°F. in February. The range between maximum and minimum temperature was greatest during this season, *i.e.*, 30°F. in February. The lowest temperature recorded was 49°F. but in some abnormal years it may fall as low as the freezing point. The humidity of the air was high and owing to great range between maximum and minimum temperatures there was copious fall of dew. This, to some extent, compensated for the paucity of rainfall during the winter season. The days were usually sunny although in normal years there is some rainfall during December and January. In Quadrat 1 investigations on the soil were carried out at seven spots (Table X) within a metre square area at surface, 6 inches and 12 inches depth. Table X shows that within this small area, some variation was found in

TABLE IX

Total Number of Plants in each Quadrat

Quadrat Number.	Sept. 1931.	Nov. 1931.	Dec. 1931.	1st week Jan. 1932.	4th week Jan. 1932.	2nd week Feb. 1932.	4th week Feb. 1932.	2nd week March 1932.	2nd week April 1932.	1st week May 1932.	1st week June 1932.	4th week June 1932.	2nd week July 1932	4th week July 1932.	2nd week Aug. 1932.	Last week Aug. 1932.
I ..	509	436	356	325	314	118	82	36	18	7	5	5	41	126	184	160
II ..	462	..	41	41	38	35	35	32	31	22	9	3	20	24	37	34
IV ..	..	123	123	108	55	40	21	19	15	7	2	2	26	29	236	532
VI ..	..	..	161	126	100	70	63	45	29	10	6	4	96	246	585	347
VII ..	..	..	205	164	122	102	96	63	45	37	30	25	128	259	337	302
VIII ..	..	..	..	87	122	119	81	74	55	40	12	0	0	127	118	93

nitrates, carbonates and water content of the soil. It may, however, be pointed out that there was no observable difference between the plants growing in this area.

The number of plants per square metre area decreased considerably during the winter season in comparison with the number in the rainy season. Ephemeral plants of the rainy season withered away, after shedding their seeds, by the end of October; others flowered and fruited during this season. The hygrophilous annuals were replaced by mesophytic annuals of temperate connections. The plants of the family compositae were dominant. Perennials lost their tropcial luxuriance. In Quadrat 1 there were (exclusive of grasses) 509 plants of 13 different species in September but in December there were only 356 plants of 8 different species.

3. *The Summer Season*:—The summer season extended from early in March till the middle of June. The first few weeks may be considered as spring. The temperature during these months gradually rose and went up as high as 120°F. The mean maximum temperature, however, was 92·7°F. in March which gradually increased to 107°F. in June. The range between Maximum and Minimum temperature decreased. The nights were only slightly cooler than the days. The dry hot winds blew fiercely throughout these months and everything seemed parched. Humidity was very low and there was no rain during this season.

The water content of the surface soil was very low, but some water was present at lower depths. There was accumulation of salts on the surface of the soil, due to the action of ground water which rose by capillarity owing to excessive evaporation on the surface. The reaction of the soil was alkaline and there was increase in the nitrate content. The main constituents of this white alkali were chlorides and sulphates of sodium.

Due to the extremes of temperature and drought all the herbaceous plants died down except in protected places where perennials were left behind. Apart from trees and shrubs the ground was bare of plants.

The month of March was characterised by dry strong winds which brought about the leaf fall of the deciduous trees. The new leaves on these trees and shrubs appeared by the end of April. It has been erroneously stated that these trees shed their leaves in order to tide over the hot weather. It is found on the other hand that these trees sprout forth and bear a new cover of leaves in the height of summer.

A. Howard (6) in his paper "On the effect of grass on trees" drew attention to this feature. The data collected by him shows that the root system of these trees is of two types, the first one

TABLE X

Investigations on the soil from seven spots in Quadrat I (17th February 1932)

Spot No.	Water Content of soil.			Hydrogen-ion Concentration (pH) of Soil.			Nitrates present in soil (Diphenylamine test.)			Total Carbonate gm. per 100 gm. of Soil.			Loss on ignition gm. per 100 gm. of Soil.		
	0″	6″	12″	0″	6″	12″	0″	6″	12″	0″	6″	12″	0″	6″	12″
1	0·80	1·93	1·31	7·0	7·1	7·0	±	±	±	1·36	1·88	0·26	4·22	3·59	2·43
2	0·12	1·78	2·75	6·9	7·1	7·1	±	++ ++	±	1·16	2·77	0·61	4·31	3·9	2·61
3	0·40	1·46	1·87	7·1	7·1	6·9	±	±	±	1·22	1·50	0·48	4·64	3·92	2·72
4	0·84	1·25	1·41	7·0	7·1	7·1	±	±	±	1·3	1·54	0·46	4·10	3·54	2·35
5	0·50	1·01	1·66	6·9	7·0	6·6	±	±	±	1·28	1·30	0·26	4·28	3·78	2·20
6	1·15	1·91	4·14	7·1	7·2	7·1	±	±	±	1·05	1·88	1·48	4·67	3·67	3·35
7	0·54	1·29	1·95	7·0	7·2	7·1	±	±	±	0·96	1·00	0·70	4·82	3·1	3·52
Average.	0·62	1·51	2·15	7·0	7·1	6·9	..	..	..	1·19	1·69	0·60	4·43	3·64	2·75

being superficial which is active during the rainy season and the second one deep seated which functions in the dry season. These trees because of their deep seated root system can draw upon the ground water during the dry season and do not suffer for the want of water. There is scanty nitrogen at the ground water level and consequently the foliage formed during this season is paler compared with those formed during the rainy season. The superficial root-system is active during the rainy season but with the increase of the dryness the activity of the root shifts downwards till in summer it reaches its lowest depth. Thus in *Mangifera indica* the active root-system in October was not found to extend beyond 3 feet 6 inches and in January not below 7 feet 6 inches and in the month of March extended to 15 feet 6 inches. The region of activity shifts downwards with the fall in ground water level. In the rainy season, however, with the rise in ground water level the root activity becomes more and more superficial. The foliage attains the deep green colour showing that nitrates are absorbed from levels nearer the surface.

Conclusions

It will be noticed from the foregoing description that the climatic factors, *e.g.*, rainfall, temperature, etc., are mainly responsible, directly, or indirectly by effecting changes in soil conditions, for bringing about seasonal changes in vegetation. The soil factors, in the quadrats studied, remained relatively constant. Within the course of a year a seasonal change of flora from tropical to temperate and to desert conditions takes place; the vegetation therefore consists of a mixed population of plants. The seasonal variation of the climatic factors is so great that a species can, only with difficulty, remain dominant throughout the year; thus restricting the number of indigenous species. According to Hooker (5), the number of indigenous species in the region (Gangetic Plain) is small, possibly amounting to 1,500 under 112 orders of which the following ten are dominant:—

1. Gramineae.
2. Leguminosae.
3. Cyperaceae.
4. Compositae.
5. Scrophulariaceae
6. Malvaceae.
7. Acanthaceae.
8. Euphorbiaceae.
9. Convolvulaceae.
10. Labiatae.

Seven of these are cosmopolitan, while Malvaceae and Convolvulaceae are temperate and Acanthaceae tropical. Of the 28 different species

met with in the quadrats studied 16 were tropical and 12 were temperate.

The classification of such a plant community presents a certain amount of difficulty, but they are conveniently grouped into Synusia. A synusium according to Gam's is an aggregation of plants which belong to the same life form and make similar demands upon a similar habitat. Saxton (8) though not adhering strictly to this definition made an attempt to classify the plants of the locality he studied into 8 synusia. A synusium in such a case will form the fundamental unit of vegetation and an association will consist of a group of synusia just as a formation consists of a group of associations.

This area is thickly populated and man exerts considerable influence upon the character of the vegetation. According to Dudgeon (3) the present vegetation is in the dry meadow stage and would develop into a deciduous monsoon forest if left undisturbed by man. It is, however, very difficult to predict without further investigation the nature of forest which would develop after the removal of man's influence. Prof. Dudgeon may perhaps be right. There is very intimate connection between the activities of man and the character of the surrounding vegetation. Man utilises the vegetable products for the necessaries of his own life and those of his domesticated animals; therefore he is responsible for interference and some destruction of the vegetation. The demand by man upon the vegetation increases with the growth of population and the vegetation in course of time attains equilibrium. From the earliest record of the vegetation of this region by Thomas Anderson (1) it appears that the vegetation of to-day is not much different from that of a century ago. The vegetation is arrested, most probably deflected, from attaining the climatic climax. It appears to be a pro-climax; the chief determining factor being man.

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FURTHER CONTRIBUTION TO OUR KNOWLEDGE OF INDIAN COPROPHILOUS FUNGI

BY

MOHAMMAD ASGHAR GINAI

Botany Department, Panjab University, Lahore

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The investigation of coprophilous fungi was started in this laboratory by Mr. N. A. Mahju, under the direction of Dr. H. Chaudhuri, the Head of the Department of University Teaching in Botany, Panjab University. Mahju investigated dungs of the following six animals, *viz.*:—Rabbit, Sambhar, Horse, Goat, Sheep and Buffalo. He described 29 species belonging to 21 genera.* The present author has investigated the dungs of 5 other animals, *viz.*: Cow, Nilghai, Camel, Zebra and Donkey, as well as that of Buffalo to find out if any other forms not noted by Mahju could be obtained. Altogether he has found 48 species belonging to 26 genera. Of these Mahju described 13 species occurring in the dungs he had examined. On buffalo dung 12 species were noted and of these 10 were new forms not noted by Mahju, bringing the total number of forms on buffalo to 17. These lists are by no means exhaustive and as work progresses, many more new forms will no doubt be noted. This work has been carried out under the guidance of Dr. Chaudhuri, to whom the author expresses his grateful thanks for manifold help.

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* N. A. Mahju—Indian Coprophilous Fungi, Journal of the Indian Botanical Society, Vol. XII, No. 2, 1933.

A table of fungi showing the species which appeared on the six different dungs during the course of the investigation (October-May) and descriptions of the species (except those given by Mahju already) are given below:—

—	Cow dung.	Nilghai dung.	Camel dung.	Zebra dung.	Donkey dung.	Buffalo dung.	REMARKS—if noted by Mahju.
1. *Mucor mucedo.*	+	..	+	..	..	+	On buffalo dung.
2. *M. griseosporus.*	..	..	+	..	..	..	..
3. *Syncephalis sphaeriea.*	..	..	..	..	+	..	..
4. *S.* sp.	..	..	..	+	..	..	..
5. *Pilobolus crystallinus.*	..	..	..	..	+	+	On buffalo dung.
6. *P. longipes.*	+	..	..	..	+	+	On buffalo dung.
7. *P. nanus.*	..	+	..	..	+	..	..
8. *P. kleini.*	..	+	..	..	..	..	..
9. *P.* sp.	..	..	..	..	+	..	..
10. *Magnusia nitida.*	+	..	..	..	..	..	On goat dung.
11. *M. barletti*	..	..	+	..	..	..	..
12. *Sordaria coprophila.*	..	..	..	+	..	..	..
13. *S. curvula.*	..	+	..	..	..	..	On horse dung.
14. *S. winteri.*	..	..	..	+	..	+	..
15. *S. decipiens.*	..	+	..	+	..	..	..
16. *Ceratostoma* sp.	..	..	..	+	..	..	..
17. *Chaetomium spirale.*	+	..	..	..	+	+	On goat dung.
18. *C. globosum.*	+	..	..	..	..	..	..
19. *Bombardia* sp.	..	..	+	..	..	..	..
20. *Sporomia minima.*	..	..	..	+	+	..	..
21. *Melachroia* sp.	+	..	..	..	..	..	..
22. *Peziza subcupilaris.*	..	..	..	..	..	+	..
23. *Humaria carpophila.*	..	..	..	..	..	+	..
24. *Humaria orthotrica.*	..	..	..	..	..	+	..
25. *Saccobolas versicolor.*	+	..	..	..	..	..	..

—	Cow dung.	Nilghai dung.	Camel dung.	Zebra dung.	Donkey dung.	Buffalo dung.	Remarks—if noted by Mahju.
26. *Ryparobius crustaceus.*	..	..	..	..	..	+	..
27. *Ascobolus minutus.*	+	..	..	..	..	+	..
28. *Stropharia semiglobata.*	..	..	+	..	..	..	..
29. *Coprinus cinereus.*	..	+	..	..	..	..	..
30. *C. stellaris.*	..	..	..	+	..	..	..
31. *C. radiatus.*	..	..	+	..	..	..	On horse dung.
32. *C. hendersonii.*	..	..	..	+	..	..	..
33. *C. ephermerus.*	..	..	..	..	..	+	On rabbit dung.
34. *C. nycthemerus.*	+	..	..	..	..	..	..
35. *C. papillatus.*	..	+	..	..	..	..	On sambhar dung.
36. *C. gibbsii*	..	..	..	+	..	..	..
37. *C. filiformis.*	+	..	..	..	..	..	..
38. *Bolbitus vitellinus.*	..	..	..	..	+	..	On horse dung.
39. *B. tener.*	..	..	..	..	+	..	..
40. *Arthobotrys superba.*	..	..	+	..	..	..	On rabbit dung.
41. *Dactylaria purpurella.*	..	..	+	..	..	..	..
42. *Acladium niveum.*	..	..	+	..	..	..	..
43. *Isaria brachiata.*	+	..	..	..	..	..	On sheep dung.
44. *Antromycopsis* sp.	..	..	..	+	..	..	..
45. *Stysanus stemonitis.*	..	+	..	..	..	..	On sheep dung.
46. *Graphium paradoxum.*	..	..	..	+	..	..	..
47. *Coremiella cystopoides.*	+	..	..	..	..	..	..
48. *Coremium* sp.	+	..	..	..	..	..	..

Descriptions of species

1. *Mucor griseosporous* (Povah) Povah, Mucor. Bull. Torr. Bot. Club 44, p. 297. Sacc. Syll. Fung. Vol. XXIV, Sect. 1.

Pl. XX. Figs. 1-3.

Sporangiophores 8 mm.-3 cms. tall, 33·5-67 μ in diameter, typically unbranched or with one or two short lateral branches ter-

minating in small sporangia, (lateral sporangia observed only in one case and that was in young stage about 25 μ in diameter). Sporangia globose, terminal, 230·5-301·5 μ in diameter, at first yellowish becoming dark grey at maturity; sporangium wall deliquescent, columella pyriform, about 105·75 $\mu \times$ 184·25 μ; spores uniform, broad elliptical, 7·4 $\times$ 14·8 μ, greyish; zygosopores not found, presumably heterothallic.

Habit: Camel dung.

Occurrence: Not very common.

2. *Syncephalis sphaerica* (Van. Tiegh.) Sacc. Syll. Fung. Vol. VII, p. 228.

Pl. XX. Figs. 4, 5.

Sparse or sub-gregarious, sporangiferous hyphae, erect, white, 1-1·5 mm. high, base broader about 67-70 μ across, gradually attenuated upwards to a thickness of 25·12 μ; head sphaeroid about 100 μ in diameter, crowded with spores; spores cylindrical, uniform, smooth, hyaline, 4·17-5·01 $\times$ 6·8-·35 μ.

Habit: Donkey dung.

Occurrence: Very rare.

3. *Syncephalis* (Van. Tiegh and Le Mon). sp. Ann. Sci. Nat. 5: 17: 261, 1873.

Pl. XX. Figs. 6-8.

Gregarious, sporangiferous hyphae white to pale, erect, 575·25-619·75 μ tall, base not inflated, slightly thinner above, 11·1-9·25 μ thick; rhizoids scanty and brief; head vesicular, ovoid, more or less like an inverted flask, 33·5 μ in diameter, upper half of the vesicle verrucose; spores cylindrical to oblong-cylindrical, smooth, hyaline, 5·84-7·4 $\mu \times$ 2·66-3·4 μ.

Habit: Zebra dung.

Occurrence: Common.

4. *Pilobolus nanus* (Van. Tiegh). Sacc. Syll. Fung. Vol. VII, p. 186.

Pl. XX. Figs. 9, 10.

Sporangiophores dwarf, 1-1·5 mm. in height, head globose, 502·5-586·35 μ in diameter, sporangiophore 117·25-134 μ across; base fusoid 211-276 μ thick; sporangium globose, dark grey 335 μ in diameter; spores spherical hyaline, minute 3·7-5·5 μ in diameter.

Habit: Nilghai and donkey dung.

Occurrence: Not very common.

5. *Pilobolas kleinii* (Van. Tiegh.) Sacc. Syll. Fung. Vol. VII, p. 185.

Pl. XX. Figs. 11, 12.

Sporangiophore 2·4 mm. tall, apex ventrico-inflated, 418·75-469 μ thick, sporangiophore 83·75-117·25 μ across, arising from a triangular base with rhizoidal connections at both the angles; sporangium globose, 519·25 μ in diameter, spores spheroideo-ellipsoid 12·95 $\times$ 5·55-7·4 μ.

Habit: Nilghai and donkey dung.

Occurrence: Not very common.

6. *Pilobolus* (Tode) sp. Schrift. Nat. Freund. Berlin 5: 46, 1784.

Pl. XX. Figs. 13, 14.

Sporangiophore 1·5-2 mm. in stature, apices globose-clavate, 234·5-301·5 μ broad; sporangiophore 150·75-284·75 μ thick, arising from a globose-triangular base with rhizoidal connection at one angle; sporangium greyish dark, globose to subglobose, 301·5 μ across; spores spheroideo-elliptical, hyaline, 7·4-8·32$\times$3·7-5·55 μ.

Habit: Donkey dung.

Occurrence: Very rare.

7. *Magnusia barletti* (Massee.) Massee and Salmon. Copro. Fungi. Annals of Botany, 1901, p. 323. Sacc. Syll. Fung. Vol. XVI, p. 1123.

Pl. XX. Figs. 15-17.

Perithecia scattered, superficial, globose, black, 335-368·5 μ in diameter, carbonaceous, fragile, texture parenchymatous, cells minute polygonal about 3·7-5·5 μ in diameter, appendages springing in a group invariably from the apex, 6-12 in number, spreading, rigid, black to fuscus, opaque, 1·52-1·75 mm. long, 3·7-5·55 μ thick, circinate at the apex, asci oblongo-pyrform, octosporous, very evanescent; spores broad elliptical, 7·4-8·32 μ $\times$ 6·43 μ hyaline or sub-hyaline.

Habit: Camel dung.

Occurrence: Common.

8. *Sordaria coprophila* (Fr.) Sacc. Syll. Fung. Vol. I, p. 230.

Pl. XX. Figs. 18-20.

Perithecia scattered or sub-gregarious, semi-immersed, 502·5-552·75 μ high, ovoido-sphaeroid, membranaceous, cells distinct and more or less parenchymatous, base globose 335-368·5 μ, gradually merging into an obtuse conical ostiole 67-83·75 μ; asci cylindraceo-subclavate, 122·1-185 μ $\times$ 14·8-25·9 μ, pedicellate, pedicel short,

distinct in the young stage, octosporous, spores more or less uniseriate, $18 \cdot 5\text{-}24 \cdot 3 \times 9 \cdot 25\text{-}11 \cdot 1$ μ, dark brown to black, beaked at the upper end, appendiculate, appendage hyaline, $29 \cdot 6\text{-}37$ $\mu \times 2 \cdot 77\text{-}3 \cdot 7$ μ; paraphyses absent.

Habit: Zebra dung.

Occurrence: Common.

9. *Sordaria winterii* (Karst.) Sacc. Syll. Fung. Vol. I, p. 234.

Pl. XX. Figs. 21-23.

Perithecia scattered or sub-gregarious, semi-immersed, yellowish black to black-violet, $703 \cdot 5\text{-}921 \cdot 25$ μ high, base ovoid, $368 \cdot 5\text{-}921 \cdot 25$ μ broad with a distinct neck, ostiole obtuse, about $117 \cdot 25$ in diameter, asci pedicellate, octosporous, cylindraceo-clavate, apex acute, $148\text{-}185$ $\mu \times 22 \cdot 2\text{-}40 \cdot 7$ μ; spore subdistichous, ellipsoid, fuscus $14 \cdot 8\text{-}18 \cdot 5 \times 25 \cdot 9\text{-}33 \cdot 3$ μ; inferior pole appendiculate, appendage hyaline, $22 \cdot 2 \times 5 \cdot 55\text{-}7 \cdot 4$ μ.

Habit: Buffalo and zebra dung.

Occurrence: Common.

10. *Sordaria decipiens* (Winter) Winter Die Deut. Sordarien, p. 92; Sacc. Syll. Fung., Vol. I, p. 235.

Pl. XX. Figs. 24, 25.

Perithecia scattered, immersed, yellowish black, $837 \cdot 5\text{-}1000$ $\mu \times 385 \cdot 25\text{-}400$ μ, globose gradually merging into a short neck osteole truncate, about $83 \cdot 75$ μ in diameter; asci elongato-cylindrical, pedicellate; $217 \cdot 75\text{-}240 \cdot 5 \times 33 \cdot 3$ μ, spores yellowish brown to dark brown biseriate, lanceolato-oblong, somewhat opaque $33 \cdot 3\text{-}37 \times 18 \cdot 5\text{-}19 \cdot 35$ μ, appendiculate, appendage hyaline $14 \cdot 8\text{-}18 \cdot 5 \times 3 \cdot 7\text{-}5 \cdot 5$ μ.

Habit: Nilghai and zebra dung.

Occurrence: Common.

11. *Ceratostoma* (Fr.) sp. Sum. Veg. Scand. 392, 1849.

Pl. XXI. Figs. 26, 27.

Perithecia gregarious to sub-gregarious, superficial or subsuperficial $1005\text{-}1172$ μ in height, membranaceo-carbonaceous, glabrous, dark-brown to black, base globose, $335\text{-}418 \cdot 75$ μ in diameter, neck slightly wavy $502 \cdot 5\text{-}586$ μ long, ostiole about $50 \cdot 25\text{-}59 \cdot 12$ μ in diameter; asci cylindrical to clavate 201 μ long, spores biseriate $25 \cdot 9\text{-}33 \cdot 3 \times 18 \cdot 5$ μ appendiculate, appendage about 10 μ long.

Habit: Zebra dung.

Occurrence: Not very common.

12. *Chaetomium globosum* (Kunze) Engler & Prantl Fam. 1 Teil. 1. Abt. p. 389, Fig. B. Sacc. Syll. Fung. Vol. I, p. 222.

Pl. XXI. Figs. 28-30.

Perithecia fuscus to black, scattered, rare globose 251·25-276 μ in diameter, submembranous, hairs spreading, long, septate, fuscus, opaque to hyaline, not spirally wound 3·72-5·5 μ thick of variable lengths, longest 1340 μ; asci clavate 83·85-100·5 μ ×16·75-33·5 μ. Pedicellate, pedicel long; spores dark broad elliptical, hyaline 14·8-15·65 × 7·4 μ.

Habit: Cow dung.

Occurrence: Very rare.

13. *Bombardia* (Fr.) sp. Sum. Veg. Scan. 389, 1849.

Pl. XXI. Figs. 31-34.

Perithecia superficial, scattered typically globoid, coriaceous to corneous, 452·25-455·5 μ in diameter, thickly clothed with long fibrous hairs, 837·5μ-1 mm. long, 1·85-3·7 μ thick, septate, internodes long or short; asci 167·5-211 μ long; spores when young yellowish black, at maturity opaque and black, rather beaked, appendiculate 14·8-16·75 μ × 22·2 μ; appendage hyaline, 32·4 × 3μ.

Habit: Camel dung.

Occurrence: Very rare.

14. *Sporomia minima* (Anersew) Sacc. Syll. Fung. Vol. II, p. 124.

Pl. XXI. Figs. 35, 36.

Perithecia sparse, immersed up to the neck, globose 117·25-167·5 μ high, 75·37-108·87 μ in diameter, ostiole minute, papilliform, 4·62-7·4 μ across; membranous glabrous; asci elongato-oblong to sub--cylindrical, pedical abrupt and short, 62·9-74 μ × 11·1-14·8μ; spores 4-celled, 3-stichous, series curved or sub-parallel, 22·2-29·6×4·62-5·55 μ, individual spore cell 5·55-7·4×5·55-4·62 μ, 1-glutinis, dark-brown to black, opaque.

Habit: Zebra and donkey dung.

Occurrence: Common.

15. *Melachroia* (Boud.) sp. Bull. Soc. Myc. Fr. 1: 112, 1885.

Pl. XXI. Figs. 37, 38.

Apothecia few, scattered, cupulate, on a subicle, 2-3 mm. in diameter, cup reddish, margin cream coloured, fimbriate, asci cylindraceo-clavate, 177·6-185 μ × 25·9 μ, turning blue with iodine, pedicellate, pedicel short, spores broad elliptical, at first hyaline then turning pale lilac to brown, 18·5-20·35 × 11·1 μ; paraphyses hyaline, aseptate, 3·7-5·5 μ thick.

Habit: Cow dung.

Occurrence: Rare.

16. *Pezia subcupilaris* (Rehm) Sacc. Syll. Fung., Vol. VIII, p. 77.

Pl. XXI. Figs. 39-41.

Sparse, sessile or sub-immersed, subglobose, yellowish orange, margin white, fimbriate, glabrous, 3-5 mm. in diameter, asci cylindrical, apices rotundate, 8-spored, $196 \cdot 1\text{-}222 \times 12\ \mu$; spores broad elliptic, glabrous $20 \cdot 35\text{-}22 \cdot 2 \times 11 \cdot 1\text{-}12 \cdot 95\ \mu$; paraphyses filiform, septate, septa indistinct, hyaline, head slightly clavate, 3-4 μ thick.

Habit: Buffalo dung.

Occurrence: Not very common.

17. *Humaria carpophila* (Bizz.) Sacc. Syll. Fung. Vol. VIII, p. 120.

Pl. XXI. Figs. 42, 43.

Ascoma substipitate or sessile, sub-gregarious 2-2·5 mm. in diameter, at first obconical, later obconico-cupulate, bright red, shining disc pale, sub-plane flocculose, margin slightly prominent: asci cylindrical, $166 \cdot 65\text{-}185\ \mu \times 18 \cdot 5\text{-}20 \cdot 35\ \mu$, dehiscence by operculum; paraphyses linear, apices granulate, spores elliptic $18\text{-}24 \cdot 3\ \mu \times 9 \cdot 25\text{-}11 \cdot 1\ \mu$.

Habit: Buffalo dung.

Occurrence: Not very common.

18. *Humaria orthotrica* (Grev.) Sacc. Syll. Fung. Vol. VIII, p. 119.

Pl. XXI. Figs. 44, 45.

Minute, apothecia sessile, sparse, cupule, hemispherical, glabrous, applanate; asci cylindrical-clavate, $148\text{-}166 \cdot 5\ \mu \times 14 \cdot 8\text{-}18 \cdot 5\ \mu$, spores elliptic, ends obtuse, slightly roughened, $18 \cdot 5\text{-}22 \cdot 2\ \mu \times 9 \cdot 25\text{-}11 \cdot 1\ \mu$; paraphyses distinctly clavate at the top, 3·7 μ thick below, 7·4 μ 12·95 μ broad at the top.

Habit: Buffalo dung.

Occurrence: Not very common.

19. *Saccobolus versicolor* (Karst) Sacc. Syll. Fung. Vol. VIII, p. 525.

Pl. XXI. Figs. 46, 47.

Minute, 335-368·5 μ high, sparse, disc convex, 418·75-502·5 μ in diameter, steel grey in colour, apices of the asci protruding out, asci oblongo-clavate, pedicellate, pedicel thick and very short, $133 \cdot 2\text{-}162\ \mu \times 22 \cdot 2\ \mu$, spores in glomerulla, (little masses), $40 \cdot 7\text{-}44 \cdot 4\ \mu \times 16 \cdot 2\text{-}18 \cdot 5\ \mu$, octosporous, spores oblong elliptic, brown to purplish brown, $16 \cdot 65\text{-}19 \cdot 42\ \mu \times 8 \cdot 32\text{-}9 \cdot 25\ \mu$; paraphyses filiform, 2-3 μ thick, hyaline, non-clavate, septate.

Habit: Cow dung.

Occurrence: Not very common.

20. *Ryparobius crustaceus* (Fuck) Sacc. Syll. Fung. Vol. VIII, p. 539.

Pl. XXI. Figs. 48, 49.

Sparse, very minute, sessile, glabrous about 148 μ high, depresso-sphaeroid to hemispherical, asci ovoideo-oblong 81·4-99·9 $\times$ 22·2 μ, spores 48-64 in number, hyaline, ovoid, to oblong-ovoid, 5·5-7·4 μ.

Habit: Buffalo dung.

Occurrence: Very rare.

21. *Ascobolus minutus* (Boud.) Sacc. Syll. Fung. Vol. VIII, p. 517.

Pl. XXI. Figs. 50, 51.

Apothecia gregarious, superficial, minute, 500-586·25 μ high, 586·25-670 μ across, convex to convexo-plane, dirty white to steel grey, yellowish grey, at maturity, glabrous, at length ruptured at the apex by protruding asci, asci cylindrical, lower portion distinguishable as stalk, numerous, arranged in vertical rows, 173·9-185 μ $\times$ 12·95-14·8 μ, octosporous, spore hyaline when young, yellowish brown at maturity, oval, striate, 16·65-18·5 $\times$ 10·17-11·1 μ; at paraphyses filiform, hyaline, surrounding the ascus, septate 5·55-7·4 μ thick.

Habit: Cow and Buffalo dung.

Occurrence: Very common.

22. *Stropharia semiglobata.* Smith British Basid. (Batsch) Rea. Brit. Basid., p. 129. Sacc. Syll. Fung. Vol. V, p. 1022.

Pl. XXII. Figs. 52, 53.

Pileus fleshy, yellowish, semiglobose, 5·5 mm. across, margins incurved, stipe 2 cm. high, 1-·5 mm. thick, darker below, white above, base villose, gills broad, pale purplish, spores purplish brown 4·59-5·01 μ $\times$ 8·35 μ.

Habit: Camel dung.

Occurrence: Very common.

23. *Coprinus cinereus* (Shaeff.) Carleton Rea. Brit. Basid., p. 504.

Pl. XXII. Figs. 54-58.

Pileus 1·5-2·5 cm. in diameter, ashy grey, disc dark, membranaceous, cylindrical, then campanulate and at length revolute, densely covered with white fugacious flocci, then naked and striate: stipe 4-6 cm. $\times$ 2·4 mm., white, equal, or slightly attenuated upwards from the thickened base, densely covered with white fugacious flocci, gills black, free, flesh of pileus, ashy-grey to dark-brown, thinner at the margin, spores dark-brown to black 9·25-11·1 μ $\times$ 5·5-7·4 μ.

Habit: Nilghai dung.

Occurrence: Common.

24. *Coprinus stellaris* (Quel.) Rea. British Basid. p. 514. Sacc. Syll. Fung. Vol. V. p. 1101. Smith Brit. Basid. (1908), p. 210.

Pl. XXII. Figs. 59, 60.

Pileus 1-2·5 mm., fleecy white, then greyish, campanulate then plane, striate, at length split in a star-like manner, crowned with very minute pellucid vesicles (remains of the universal veil), stipe 1·5-2·5 mm., translucent, velvety with silky white hairs, gills greyish, then brown, adnate, narrow; spores brown elliptical, 4·62 $\mu \times$ 7·4-8·32 μ.

Habit: Zebra dung.

Occurrence: Rare.

25. *Coprinus hendersonii* (Berk.) Rea. British Basid. p. 510. Sacc. Syll. Fung. Vol. V, p. 1097. Smith. Brit. Basid (1908), p. 208.

Pl. XXII. Figs. 61, 62.

Pileus 10-17 mm., white to ashy, white, disc brownish, membranaceous, cylindrical, then ovali-campanulate at length plane, minutely granular under the lens; stipe 7-9 cm. $\times$ 2-4 mm., white, attenuated upwards nearly or quite smooth; gills white then brownish, free, distant; flesh white very thin; spores purplish brown to black, 7·42-11·5 $\mu \times$ 5·5-7·4 μ, ovoideo-elliptical, semiapiculate.

Habit: Zebra dung.

Occurrence: Not very common.

26. *Coprinus nycthemerus.* Rea. British Basid., p. 511. Sacc. Syll. Fung. Vol. V, p. 1100, Smith. Brit. Basid. (1908) p. 209.

Pl. XXII. Figs. 63, 64.

Pileus 5-7 mm., grey, disc dark brown, very tender, conical, then flattened, soon opening into furrows, fur furaceo-floccose, at length naked and forked striate; stipe 3·5-4·5 cm. $\times$ 1-1·5 mm., whitish or pale oblong-ovoid dark-brown 7·4-10·17 $\mu \times$ 5·55 μ.

Habit: Cow dung.

Occurrence: Rare.

27. *Coprinus gibbsii* (Massee and Crossland) Rea. Brit. Basid. p. 514. Smith Brit. Basid. (1908), p. 209.

Pl. XXII. Figs. 65-67.

Pileus 753·75 μ, inseparable from the stipe, greyish white, campanulate then revolute; in revolute position 586·25 μ across, thin; stipe 1·2 cm. high, 217·75-50·25 μ thick, arising from a more or

less bulbous base and gradually attenuated upwards; flesh of the pileus pale white; spores 7-7·4 × 3-3·7 μ, reddish brown, broad elliptical.

Habit: Zebra dung.

Occurrence: Very rare.

28. *Coprinus filiformis* (B. and Br.) Rea. Brit. Basid. p. 517. Smith, Brit. Basid. (1908), p. 211.

Pl. XXII. Figs. 68-70.

Pileus 1507·5 μ across, greyish white, thin, conical then expanded and finally revolute, pileus inseparable from the stipe; stipe about 3 cm. × 502·5-375 μ, covered with floccose hairs; spores dark brown to brownish black, oblong to broad elliptical 9·2 × 8·6 μ, smallest 7·4 × 7 μ.

Habit: Nilghai dung, old.

Occurrence: Very rare.

29. *Bolbitus tener* (Berk.) Carleton Rea. British Basid. p. 499. Sacc. Syll. Fung. Vol. V, p. 1076.

Pl. XXII. Figs. 71, 72.

Pileus 3·5-5 mm., flesh coloured with yellowish tinge; tender, conical 3 mm. high, smooth; stipe 4·5 cm. high, white, base thickened, attenuated upwards; gills free, narrow, not crowded; spores elliptical, 13·87-14·8 μ × 9·25-11·1 μ yellowish-brown to brown.

Habit: Donkey dung, old.

Occurrence: Very rare.

30. *Dictylaria purpurella* (Sacc.) Sacc. Syll. Fung. Vol. IV, p. 195.

Pl. XXII. Figs. 73, 74.

Fertile hyphae erect, dense, gregarious, of dilute purple colour, conidiophore 129·5-296 μ tall, about 7·4 μ thick, gradually attenuated upwards to a thickness of 1·85 μ; head slightly dilated and denticulate, spores variously arranged; spores (conidia) 22·2-25·9 × 4μ, ends obtuse to acute, 2-3 septate.

Habit: Camel dung.

Occurrence: Common.

31. *Acladium niveum* (Lev.) Sacc. Syll. Fung. Vol. IV, p. 87.

Pl. XXII. Figs. 75-78.

Sterile hyphae prostrate, branched, fertile hyphae erect or drooping, densely gregarious, of variable heights, simple or ramose, gradually attenuated above, 7·4-1·85 μ thick, septate, internodes 3·7-1·85 μ long, cells imperceptibly swollen at the node; conidia

smooth, white, globose, 5·55-7·4 μ in diameter, pleurogenous, borne more or less irregularly at intervals, in glomerula (little masses) on club shaped conidiophores, conidia adhere together even after discharge.

Habit: Camel dung.

Occurrence: Common, forming cottony masses.

32. *Antromycopsis* (Pat and Trab.) sp. Bull. Soc. Myc. Fr. 13: 215, 1897.

Pl. XXII. Fig. 79.

Synema scattered or sub-gregarious, rigid, black, glabrous, 1-1·5 mm. high, 16·75-33·5 μ thick, capitule compact, sub-globose 41·87 μ high, 83·75 μ broad, hyphae of the capitule compact; conidia oblongo-cylindrical, very minute 1-2 septate, septa clear under high magnification, dark hyaline, 3·7-5·55 × 1·85-2 μ.

Habit: Zebra dung.

Occurrence: Rare.

33. *Graphium paradoxum* (Sacc.) Sacc. Syll. Fung. Vol. XVI. p. 1087.

Pl. XXII. Figs. 80, 81.

Gregarious olivaceo-fuscus, at first greyish, stroma vertical or oblique, 251·25-418·75 μ tall, 7·4 μ to 29·6 μ thick, component hyphae dense fasciculate (bundled), septate, smooth, about 1·67 μ thick, erect, ramose above, conidia ovoid to broad elliptical 4·75-5·84 μ × 1·67-3·34 μ, hyaline or hyalino-olivaceous.

Habit: Zebra dung.

Occurrence: Rare.

34. *Coremiella cystopoides* (Bub. and Krieg.) Sacc. Syll. Fung. Vol. XXV, p. 927.

Pl. XXII. Figs. 82, 83.

Synema scattered or sub-gregarious, white to dark grey, 7-12 mm. high, narrow below and thicker above to form a more or less club-like structure, 5-1·15 mm. in diameter, peripheral tissue of the synema bark-like thickly clothed with fibres, head globose about 1 mm. high, 1·25 mm. across, bearing conidia in spirals, hyaline, smooth, acropetally arranged, 24·37 μ to 67 μ in diameter, spherical.

Habit: Cow dung.

Occurrence: Common.

35. *Coremium* (Link.) sp. Sp. Pl. Fung.. 71, 1824.

Pl. XXII. Fig. 84.

Scattered or sub-gregarious, stem 85·1-111 μ high composed of septate hyphae running parallel to one another 7·4-18·5 μ thick, slightly spreading above to a breadth of 18·5-37·4 μ; conidia smooth, hyaline, broad elliptic to sphaeroid 3·7 μ × 5·5 μ.

Habit: Cow dung.

Occurrence: Common.

Explanation of Plates

Plate XX

Mucor griseosporus

Fig. 1. Terminal part of the sporangiophore with the sporangium. × 60.
Fig. 2. Columella. × 60.
Fig. 3. Spores from the sporangium. × 255.

Syncephalis sphaerica

Fig. 4. Sporangiophore with the terminal head crowded with exogenously borne spores. × 60.
Fig. 5. Spores of the same. × 255.

Syncephalis sp.

Fig. 6. Sporangiophore with the vesicular head bearing spores. × 60.
Fig. 7. Vesicular head magnified. × 255.
Fig. 8. Spores of the same. × 550.

Pilobolus nanus

Fig. 9. Sporangiophore with terminal sporangium. × 20.
Fig. 10. Spores. × 255.

Pilobolus kleinii

Fig. 11. Sporangiophore with the sporangium. × 20.
Fig. 12. Spores from the sporangium. × 255.

Pilobolus sp.

Fig. 13. Sporangiophore. × 20.
Fig. 14. Spores from the sporangium. × 255.

Magnusia barletti

Fig. 15. Perithecium showing general habit. × 35.
Fig. 16. Ascus. × 255.
Fig. 17. Ascospores from the ascus. × 550.

Sordaria coprophila

Fig. 18. Perithecium showing general habit. × 60.
Fig. 19. Ascus. × 255.
Fig. 20. Ascospores. × 255.

Sordaria winterii

Fig. 21. Perithecium. × 60.
Fig. 22. Young ascus in outline. × 255.
Fig. 23. Mature ascus. × 255.

Sordaria decipiens

Fig. 24. Perithecium. × 60.
Fig. 25. Ascus with mature spores. × 255.

PLATE XXI

Ceratostoma sp.

Fig. 26. Perithecium. × 60.
Fig. 27. Ascospores. × 255.

Chaetomium globosum

Fig. 28. Perithecium with appendages. × 60.
Fig. 29. A mature ascus. × 255.
Fig. 30. Ascospores. × 255.

Bombardia sp.

Fig. 31. Perithecium. × 20.
Fig. 32. Part of the appendage magnified. × 255.
Fig. 33. Ascus. ×255.
Fig. 34. Ascospores. × 255.

Sporomia minima.

Fig. 35. Perithecia showing general habit. × 60.
Fig. 36. Mature ascus containing ascospores. ×425.

Melachroia sp.

Fig. 37. Apothecium on a subicle. × 2.
Fig. 38. Ascus and paraphyses of the same. × 255.

Peziza subcupileris

Figs. 39, 40. Apothecia showing general habit. × 2.
Fig. 41. Ascus and paraphyses. × 55.

Humaria carpophila

Fig. 42. Apothecium. × 2.
Fig. 43. Paraphyses and ascus containing ascospores. × 255.

Humaria orthotrica

Fig. 44. Apothecium showing the general habit. $\times 2$.
Fig. 45. Paraphyses and ascus. $\times 255$.

Saccobolus versicolor.

Fig. 46. Apothecium. $\times 15$.
Fig. 47. Paraphyses and ascus containing ascospores. $\times 255$.

Ryparobius crustaceus

Fig. 48. Apothecium showing general habit. $\times 60$.
Fig. 49. Ascus of the same. $\times 255$.

Ascobolus minutus

Fig. 50. Apothecium. $\times 15$.
Fig. 51. Ascus containing ascospores and paraphyses. $\times 255$.

PLATE XXII

Stropharia semiglobata

Fig. 52. Upper part of the plant with the pileus. $\times 2$.
Fig. 53. Spores. $\times 425$.

Coprinus cinereus

Fig. 54. Entire plant, showing general habit. $\times \frac{1}{2}$.
Fig. 55. Pileus of the same in revolute position. $\times \frac{1}{2}$.
Fig. 56. Basidium bearing basidiospores. $\times 255$.
Fig. 57. Photo taken in the afternoon. $\times$ approx. $\frac{1}{2}$.
Fig. 58. Photo taken next morning. $\times$ approx. $\frac{1}{2}$.

Coprinus stellaris

Fig. 59. Upper part of the plant bearing the pileus. $\times 2$.
Fig. 60. Spores. $\times 425$.

Coprinus hendersonii

Fig. 61. Upper part of the plant. $\times 2$.
Fig. 62. Spores of the same. $\times 425$.

Coprinus nycthemerus

Fig. 63. Upper part of the plant with the pileus. $\times 2$.
Fig. 64. Spores of the same. $\times 425$.

Coprinus gibbsii

Fig. 65. Upper part of the plant with the pileus. $\times 20$.
Fig. 66. Basal part of the same. $\times 20$.
Fig. 67. Spores. $\times 425$.

Coprinus filiformis

Fig. 68. Upper part of the plant bearing the pileus. × 20.
Fig. 69. Basal part of the same. × 20.
Fig. 70. Spores. × 425.

Bolbitus tener

Fig. 71. Upper part of the plant. × 2.
Fig. 72. Spores. × 425.

Dactylaria purpurella

Fig. 73. Fertile hypha with terminal cluster of spores. × 255.
Fig. 74. Spores. × 255.

Acladium niveum

Fig. 75. A part of the fertile hypha bearing clusters of conidia at intervals. × 255.
Fig. 76. Basal part of the erect hypha showing its emergence from the prostrate hyphae and its mode of branching. × 550.
Fig. 77. Upper part of the fertile hypha showing the arrangement of conidiophores and conidia. × 550.
Fig. 78. Conidia of varying size and design. × 550.

Antromycopsis sp.

Fig. 79. Synema showing general habit. × 60.

Graphium paradoxum

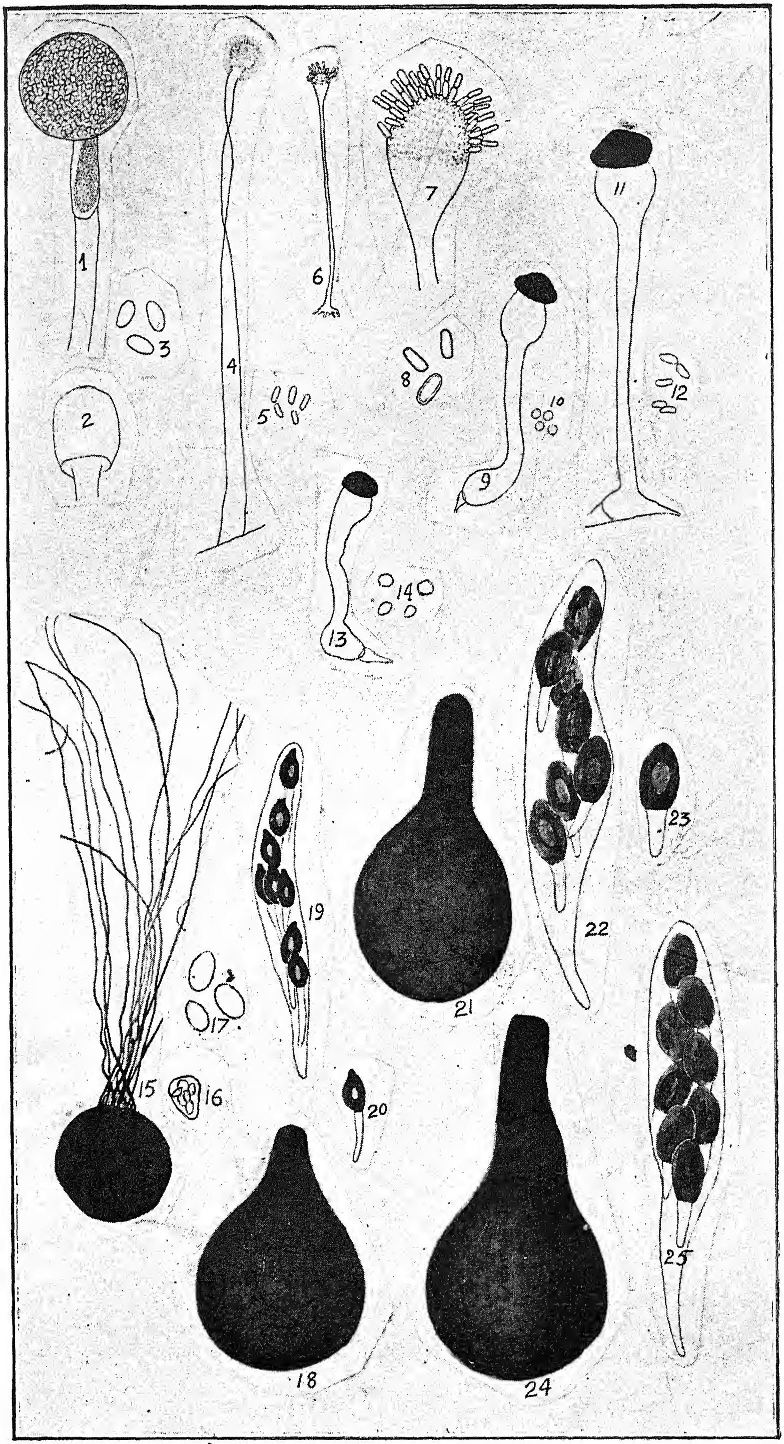
Fig. 80. Synema showing general habit. × 250.
Fig. 81. Terminal part of the synema magnified. × 550.

Coremiella cystopoides

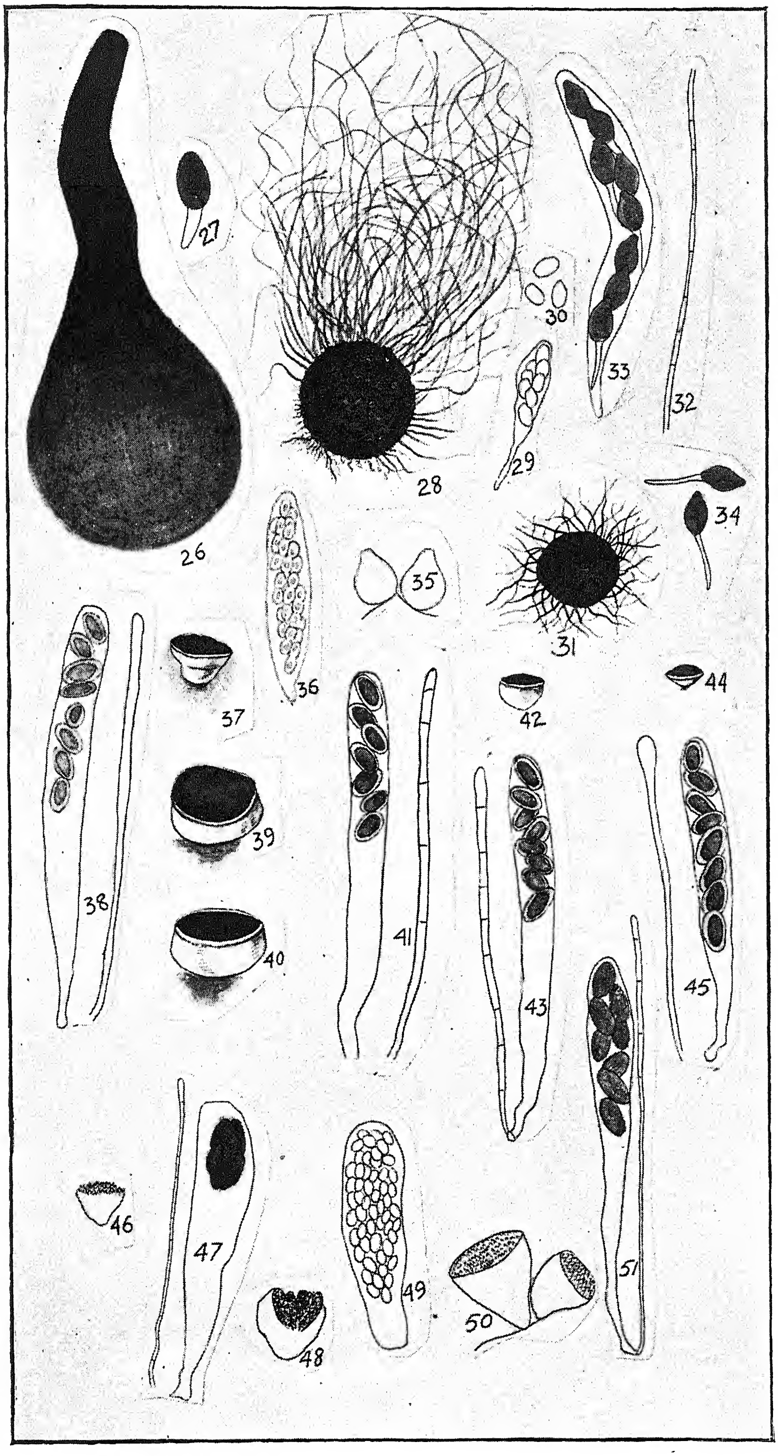
Fig. 82. Synema showing general habit. × $2\frac{1}{2}$.
Fig. 83. Spores of the same. × 60.

Coremium sp.

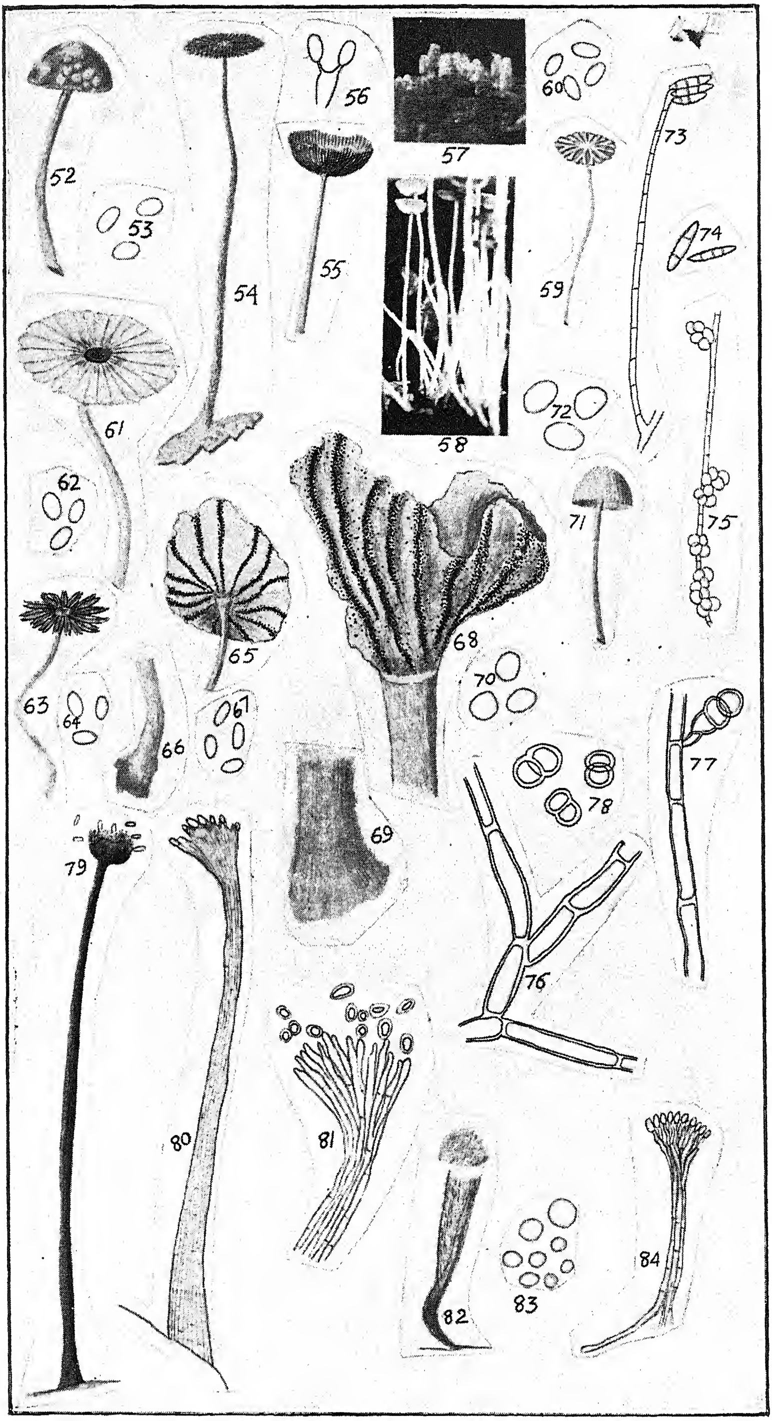
Fig. 84. Synema showing general habit. × 255.



M. ASGHAR GINAI—*INDIAN COPROPHILOUS FUNGI.*



M. ASGHAR GINAI—*INDIAN COPROPHILOUS FUNGI.*



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STUDIES ON THE MYXOPHYCEAE OF LOWER BENGAL

I. Preliminary observations on the group in relation to salient ecological factors and systematic enumeration of a few Chroococcaceae

BY

JOGENDRA CHANDRA BANERJI, M.A.

(Department of Botany, Calcutta University)

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I. Introduction

Our knowledge regarding the algal flora of Bengal is comparatively meagre and rests chiefly upon the foundation laid by the works* of Martens (27), Turner (32), Prain (30), West W. & G. S. (34), Nellie Carter (11), Brühl and Biswas (9 and 10), and Biswas (3-6). These works, however, do not give a true picture of the Myxophyceae of this region as the authors have dealt with a few forms only in a casual manner.

Myxophyceae are the dominant group of algae in all the tropical countries, and general agreement appears to prevail regarding the causes of their dominance. High temperature, a moist substratum and high relative humidity of the air, specially during the rains, provide very suitable conditions for their development. Variations in light partly influence their distribution and growth.

A comparative study of the constituents of the phytoplankton of the bigger pieces of stagnant fresh-waters, at different seasons, shows the abundance of blue-green element. It is particularly so during the summer when the temperature of the water and the concentration of its contents reach the maximum and the intensity of illumination is great. Some of the forms show temperature preferences by becoming abundant or rare with its rise and fall. Others, however, have a large degree of tolerance for variations in temperature although they are seldom as abundant during the cold season. Myxophyceae are very well known to prosper in a medium containing dissolved organic substances. The masses of water of the locality are generally rich in organic contents and they are characterised by a rich growth of water weeds. Views of Fritsch

* To avoid lengthy bibliography, only the most important literature has been referred to in the text.

(16 and 17), Griffiths (25), and Pearsall (29) differ regarding the relative importance of the above noted factors in promoting the development of this group of plants.

The main purpose of this series is to make a comparative study of this group of plants and to record in a systematic way as many forms as could be collected from the diverse habitats of Lower Bengal. An attempt has also been made to correlate the main climatological factors, as obtained in Lower Bengal during 1933 (see the table below), with the salient features of the observed and investigated seasonal variations of the sub-aërial and planktonic Myxophyceae floating on the surface of ponds, tanks, lakes, Jheels, etc. A few members of the Chroococcaceae, that could be collected, have also been systematically enumerated at the end of this paper. The species marked with asterisk are reported for the first time from India and those marked with + are new records for this province. One of the species is new to science.

Materials for this investigation were collected from time to time from various parts of the districts of 24 Pergannahs, Jessore, Faridpur, Dacca, and Mymensingh. Various sub-aërial and aquatic habitats, in and near about Calcutta, are still being studied systematically with a view to verify the results embodied in this contribution.

II. Analysis of the Main Climatological Factors * in Relation to Periodicity and Distribution of Myxophyceae.

The climate of Lower Bengal is characteristically damp. The three seasons—the cool, the hot and the rainy—are well represented here. The annual average rainfall of each rainy day on the plains of Bengal is between five and seven-tenths of an inch. The number of rainy days amounts, on an average, to 118 at Calcutta which has an annual rainfall of 65½ inches, Jessore of 68 inches and Dacca of 74 inches. Heavy and continuous rains in the first or second week of June usher in the monsoons. Such bursts of rain continue through July and August interrupted by occasional rainless intervals. The air remains surcharged with moisture right up to the end of September. The atmospheric humidity and temperature provide very suitable conditions at this time for the development of Myxophycean maxima on almost all the absorbent materials out of doors that reek with moisture. Rains are less frequent in October and November; they are exceptional in December, although there are

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* I am grateful to Dr. S. N. Sen, Meteorologist, Calcutta, for his very kindly supplying the data for 1933. The others have been collected from :—

(*a*) Blanford, H. F.—A practical guide to the climate and weather of India etc., (London), 1889.

(*b*) Sohoni, V. V.—Meteorological normals of Calcutta. Journ. & Proc. of As. Soc., Bengal, New series. Vol. XXV, No. I.

generally two or three rainy days in January and February. The records of temperature, etc., in the table below are fairly representative of those of Lower Bengal during the year under observation.

TABLE I

Shows the monthly average maximum and minimum shade temperature and the monthly average relative humidity during the year 1933 as recorded in the Alipore (Calcutta) Observatory.

Months.	Average maximum temperature, O F.	Average minimum temperature. O F.	Average relative humidity, %
January ..	76	54	67
February ..	83	64	72
March ..	93	71	58
April ..	95	75	67
May ..	94	77	76
June ..	91	79	82
July ..	88	79	87
August ..	88	78	87
September ..	88	78	85
October ..	88	75	82
November ..	83	66	72
December ..	78	58	75

During the rains the land surface temperature ranges approximately between 80°-97°F. The relative humidity of the air is considerably greater than the rest of the year, whilst the temperature and intensity of illumination are lower than those of the summer. In correspondence with these, a very marked increase in the development of the sub-aërial Myxophyceae is found. The heavier and more copious the rain-fall in a locality, the more abundantly the blue-greens prevail. Relative dryness of the atmosphere and substrata, at other seasons of the year, are not suitable for such abundant growth.

Of the filamentous forms, *Oscillatoria* dominates the land communities intermingled with *Lyngbya, Phormidium, Nostoc, Scytonema, Tolypothrix* and *Microcoleus*. Vertical tufts of inter-twined

filaments of *Schizothrix* and *Symploca,* as mentioned by Fritsch (17) in Ceylon, are rarely to be met with. Of the unicellular and colonial forms, *Aphanocapsa* and *Gloeocapsa* are often found associated with the filamentous forms noted above. *Chroococcus* and Diatoms are also found admixed with them. The advent of sea-water, at certain localities, introduces some modifying factors. "The Flora of the Salt-lakes of Calcutta" (5) may be referred to in this connection.

The temperature of water round the margins of the bigger pieces of water, under observations throughout the rainy season of 1933, ranged approximately between 55°-65°F. Whenever floating algal flora was developed on the surface of these ponds, etc., Myxophyceae predominated. Entangled filamentous masses of blue-greens, sometimes in association with *Spirogyra, Rhizoclonium, Oedogonium* and *Pithophora,* characterise the floating algal flora during the rains and autumn. *Lyngbya* sp. very often appears to dominate. Attached, filamentous forms are frequently to be met with, while such unicellular colonies are almost lacking. *Microcystis* sp., which very often blooms during the summer, is generally not very conspicuous during these seasons. Diatoms and Desmids are common. *Chara* and *Nitella* are very often met with.

The highest air temperature is recorded in April or more frequently in May. The percentage of atmospheric humidity during this period, falls considerably in comparison with that of the period extending from June to October. There is a general rise of temperature and on rare occasions it goes even up to 113°F. The temperature of the surface of land varies approximately between 76°-112°F. The highest readings of the solar radiation thermometer generally vary between 159°-165°F. Such conditions are quite unsuitable for the development of any algae on the exposed substrata specially when there is a lack of sufficient moisture. Most of the moist habitats, along with the algal layers already existing on them, dry up during this period. In moist, shady localities, some of the forms maintain themselves and continue their development. The following forms could be collected from such habitats during the summer of 1933:—*Gloeocapsa* (*quaternaria, gelatinosa*), *Scytonema mirabile, Oscillatoria* (*tenuis, amphibia*), *Pormidium tenue, Lyngbya aeruginea-coerulea, Microcoleus chthonoplastes* and *Nostoc commune*.

The temperature of the surface layers of the water, as taken by me, round the margins of some of the big, deeper ponds on hot sunny days, ranged approximately between 57°-70°F. The special feature during this period of maximum heat and intense illumination, is the copious development of *Microcystis* on the surface of most of the bigger pieces of water which are fully exposed to the wind and light. Wherever this form predominates and forms blooms, most of the other algal forms, already prevailing, either completely disappear or remnants of them persist as its associates.

The lowest temperature occurs, as a rule, in January or sometimes in February. Myxophyceae do not play a very prominent part during the winter. Filamentous blue-greens, which often dominate from the summer to autumn, are not so conspicuous during this season. *Microcystis* predominates again in some of the waters in spring. The results of further observations will be published in a separate paper.

III. The Sub-aërial Myxophyceae.

Although Myxophyceae form a dense covering on almost all the conceivable sub-aërial habitats from the middle of July to the end of October, moist localities only bear thin films of these at other times of the year. With the advent of the monsoons, *Oscillatoria, Phormidium* and *Lyngbya* generally appear first on low lands moistened by stagnation of rain water. The members of the genera, sometimes in association with *Aphanocapsa, Gloeocapsa Nostoc, Chroococcus* and Diatoms form layers on sub-aërial habitats when all the absorbent materials are completely saturated with moisture. *Scytonema, Tolypothrix* and *Microcoleus* often invade the former layers in sufficient numbers. About the middle of July, Myxophyceae reach the maximum development on every possible moist habitats such as soil, bricks, cemented plinths, tree trunks, perpendicular walls, stones, etc. In a few cases the development is found to be so profuse that it determines the colour of acres of land. Almost pure layers of *Oscillatoria* of several square yards extent are of common occurrence and *Oscillatoria tenuis* appears to be the dominant species. Adhesive layers of unicellular and colonial Myxophyceae are not of such frequent occurrence. Though they are common on pathways and in grassy plots during rains. The following unicellular forms could be collected from diverse sub-aërial habitats:— *Aphanocapsa* (*Grevillei, montana*), *Chroococcus* (*turgidus, minutus*), *Gloeocapsa* (*quaternaria, montana, atrata, gelatinosa*).

Exposed vertical walls and hard barks of trees are rarely provided with an algal covering during the earlier part of rains. Such habitats are generally dominated by Myxophyceae when these are completely saturated with moisture. Species of *Oscillatoria, Lyngbya, Scytonema,* and *Tolypothrix* often form big coherent sheets with unicellular colonies scattered among them. Decayed, exposed trunks of trees and old walls often bear a rich growth of Myxophyceae after a few heavy showers. While mosses, *Cyathodium, Riccia* and other Liverworts often grow in plenty on such shaded substrata. *Lyngbya* sp. is sometimes found here to use mosses as a kind of support round which its filaments twine closely and thus coming to the surface forms a thin, interwoven, spreading tangle.

Pure layers of green algae are very rarely to be met with on exposed sub-aërial habitats. Small patches of them are found scattered among the blue-green layers in a very subordinate amount.

Reddish-yellow tufts of *Trentepohlia* are relatively frequent on trunks of trees, while small patches of *Protococcus viridis* are of rare occurrence. *Botrydium* sp. is not very rare on drying up muds. Species of *Spirogyra* and *Pithophora* are sometimes to be met with in low lands where rain-water stagnates at least during certain part of the season. I have not come across a single form of *Vaucheria* from terrestrial habitats. A few other green forms are sometimes found in moist, shady habitats to form patches during the winter and the rains.

Rice fields, shortly after planting and harvesting, are among the best collecting places for Myxophyceae, which often cover the soil as a thin film until the rice plants reach certain height and shade the fields. After harvesting, this group of plants preponderates again. Green forms sometimes dominate while the fields are shaded by rich growth of paddy plants. But floating patches, composed of *Oscillatoria, Phormidium, Anabaena* and *Aphanocapsa* are often found round the margins of the fields, during July and August, when they are under water.

A sample of dry soil was collected from a paddy field of Faridpur in November for the study of algae contained therein. The soil was air-dried, sieved and series of cultures were set up under a complete aseptic condition with Bristol's aqueous mineral salt solutions. Several species of *Phormidium, Nostoc, Fischerella* and *Tolypothrix* developed in the cultures. A note on the results of this investigation has already been published (1).

IV. Blue-Green Phytoplankton of the Larger Pieces of Fresh-Water.

The composition of the phytoplankton communities, studied by me, differs widely from that of the terrestrial communities. They do not exhibit the extreme seasonal fluctuations to which the land communities are subjected. Difference in degrees of temperature of water and variations in its organic contents affect them by retarding or accelerating their growth and are mainly responsible for the composition of this flora. The following discussion is primarily based on planktonic blue-green predominants or prevalents which are chiefly the products of seasonal and other changes. Local factors have also been taken into consideration.

The essential ecological conditions, influencing the character of the phytoplankton flora, are much the same in almost all the pieces of fresh-water under observation. Masses of decomposing water weeds and leaves of trees often form the bottom of most of them. The colour of the water and an unpleasant odour emitting from it often testify to the richness of the water in organic contents. One is struck by the fact that in a considerable number of them the phytoplankton is completely dominated by the blue-greens almost throughout the year. These habitats also often nearly agree

with the others in presenting certain dominants at certain seasons. As soon as other conditions permit, these seasonals appear very scanty. They continue to develop and increase in numbers if all the conditions remain favourable. Change of climate, however, often cause some of these dominants to drop out and get replaced by some other members of the same group or green ones. It is also sometimes obvious that several species occur together with no clearly defined dominant forms and the constituent elements of different pieces of water vary under the same conditions of temperature and illumination. The exact factors leading to this diversity are difficult to determine. Variations in luxuriance of the growth of floating, suspended or rooted macrophytes also cause changes in connection with existence or abundance of some particular types. Microphytoplankton is particularly abundant in those pieces of water where there is a sparse vegetation of rooted phanerogams at the bottom and almost an entire absence of suspended and floating macrophytes. Tangled patches of filamentous forms are, however, frequent in the bodies of water invaded by a comparatively dense mass of macrophytic flora. The lower percentage of dissolved oxygen in water is one of the chief factors in influencing the aquatic vegetation of the tropics.

Spirulina platensis forms blooms of considerable thickness in waters very rich in organic contents. *Oscillatoria formosa* also forms a thin, pure scum over the surface of such waters, while *Anabaena circinalis* forms a thin scum, during late summer, over the surface of waters not so rich in organic contents.

An extensive survey of the phytoplankton, during the summer, shows an abundance of *Microcystis aeruginosa* and *Microcystis flos-aquae* in most of the bodies of water where there is a sparse phanerogamic vegetation. Whenever there is a luxuriant growth of these macrophytes, these algae are either entirely absent or very poorly developed. They begin to appear in larger numbers generally from the latter part of January and reach the maximum development during late summer when the concentration of the organic contents of water reaches the maximum. Sometimes the development is so profuse that blooms of even about half an inch thick are formed. This 'water-bloom' may occur annually in the same ponds, etc., during this season or may be sporadic. Wherever such a bloom occurs, the passage of light to the submerged vegetation is prevented and consequently, the latter dies and decomposes. The above named predominant species of *Microcystis* are very often associated with a few or several of the following forms:—*Chroococcus turgidus, C. minutus, Oscillatoria tenuis, Phormidium tenue, Merismopedia elegans, M. glauca, Spirulina major, Anabaena flos-aquae, Pediastrum clathrata, Chlorella vulgaris, Scenedesmus quadricauda* and *Euglena viridis,* while Diatoms, Desmids and mucous nodules of *Gloeotrichia pisum* are not uncommon.

Sometimes *Microcystis scripta* and *M. robusta* could be found to reach the abundance of the former species, while *Microcystis marginata, M. viridis* and *M. pseudofilamentosa* were found forming very thin films over the surface of two of the fresh-water ponds near Calcutta. The plankton composed chiefly of *Microcystis,* often completely disappears after several heavy showers at the advent of monsoons. Occasionally, however, it gains the upper hand again during the autumn.

Tangled masses of floating filamentous algae are commonly met with in some of the other bodies of water not inhabitated by dense growth of *Microcystis.* This plankton floats on the surface as large frothy masses of threads in association with a large number of epiphytic, smaller, blue-green, green and brown (Diatoms) algae. Myxophyceae are found to be abundant here also, especially during summer and autumn. Some of the blue-green members of this flora also disappear after several heavy showers at the beginning of monsoons, while others continue their existence throughout the year. Pure and mixed up patches of *Lyngbya majuscula, L. aerugineo-coerulea, Oscillatoria princeps, O. tenuis, Spirulina major, Anabaena sphaerica, A. flos-aquae, Anabaena* sp. and *Nostoc* sp. are often met with throughout summer and autumn. Attached forms of *Microchaete* and *Calothrix* are also not rare. *Spirogyra, Pithophora, Oedogonium* and a few other filamentous green forms are of frequent occurrence during the period extending from the rains to the cold season. One species of *Zygnema* was once collected from a pond during the cold season. I did not come across any filament of *Ulothrix* or *Vaucheria* from the aquatic habitats. *Compsopogon* sp. is sometimes found forming floating masses. Among the filamentous blue-greens, *Lyngbya* appears to be the predominant genus in fresh-water habitats under observation.

Gregarious growth of floating macrophytes—*Pistia, Lemna, Wolffia, Salvinia, Azolla* and *Eichhornia crassipes*—sometimes completely checks the growth of all the pre-existing algal forms by cutting off the light completely from the lower layers. Often most of the algae die and sink to the bottom, while others, conditions permitting, float in small patches or get attached to the submerged parts of the above named macrophytes.

Not much can be said regarding the geographical distribution of the Myxophyceae. The views of different authors regarding the limits of genera vary considerably. Geitler (20) is of opinion that most of them are probably cosmopolitan. According to him, the difficulty in correctly determining many species of Myxophyceae, the possibility of specimens from certain localities having been investigated and overlooked, as a rule, from certain others, are among the causes which do not permit of any conclusions being drawn regarding their geographical distribution. Under the circumstances, no mention is made of the geographical distribution of the species recorded in the following pages.

V. Systematic Enumeration of the Chroococcaceae.

MICROCYSTIS. Kütz. 1883.

*1. *Microcystis viridis* (A. Br.), Lemm., *Abh. Nat. Ver. Bremen.*, XVII, 1902, p. 342. (Fig. 1, A.)

Colonies composed of a group of partial colonies surrounded by a common sheath. Frequently the compound colonies break up into partial colonies which again form compound colonies.

Lat. cell., 3-6·5 μ

Habitat:—Planktonic, forming a very thin film over the surface of a stagnant pond.

2. *Microcystis marginata* (Menegh.) Kütz. *Tab. Phyc.* I, p. 6, pl. 8, 1845-49. Geitler, in Rabenhorst's *Kryptogamen-flora von Europe,* XIV, *Cyanophyceae,* p. 136-37, Fig. 59a-c. 1930-32.

Colonies with broad, distinct sheaths, clearly stratified, specially, in older ones.

Lat. cell, 4-6 μ.

Habitat:—Planktonic in a stagnant pond. Brühl and Biswas (9) reported from barks of trees, Bengal.

3. *Microcystis aeruginosa* Kütz., *op. cit.,* p. 6, pl. 8, Geitler, *op. cit.,* p. 137. Fig. 59d. (Fig. 1, B.)

Colonies of various fantastic shapes, show transitional stages often mistaken for *Microcystis flos-aquae.* Sheath indistinct.

Lat. cell, 3-6 μ.

Habitat:—Planktonic in stagnant, unshaded bodies of freshwater almost all the year round. Often forming thick 'bloom' of various colours during the summer.

4. *Microcystis flos-aquae* (Wittr.) Kirchn. in Engler-Prantl *Nat. Pflanzenfamilien.* I. la., p. 56, 1900. Geitler, *op. cit.,* p. 138, Fig. 59e, f.

Younger colonies have wide distinct sheaths which are often indistinct in older ones. The process of actual formation of daughter colonies could be observed in one of the collections very clearly. (Fig. I, C.).

Lat. cell, 3-7 μ.

Habitat:—Planktonic in stagnant, unshaded bodies of freshwater almost throughout the year. Often forming thick scum of different colours during the summer.

*5. *Microcystis protocystis* Crow, *Taxon. and variat. genus Micr. in Ceylon. New Phyt.*, XXII. p. 62. pl. I, Fig. D, 1923. Geitler *op. cit.*, p. 140, Fig. 62b (Fig. 1, D.)

Colonies irregular, diffuse, with indistinct sheaths. The distances between adjacent cells varying between one to four times the cell diameter.

Lat. cell, 3·5-6 μ.

Habitat:—Planktonic in a stagnant pond.

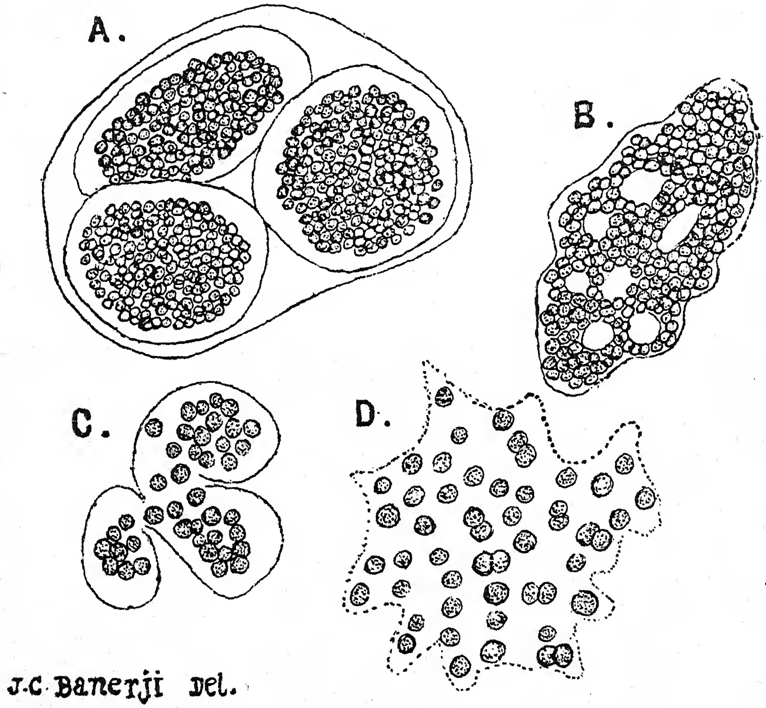

Fig. 1. A. *Microcystis viridis* colony ×260. B. *M. aeruginosa*, a typical colony ×200. C. *M. flos-aquae*, mother colony breaking up into daughter colonies ×260. D. *M. protocystis* colony. ×550.

*6. *Microcystis scripta* (Richter.) Geitler, *op. cit.*, p. 139. Fig. 62a.

Colonies deeply lobed and of letter-like structures, frequently breaking down; sheath not distinct.

Lat. cell. 4-6·5μ.

Habitat:—Planktonic in a stagnant pond.

7. *Microcystis robusta* (Clark.) Nygaard. Geitler, *op. cit.*, p. 135. Fig. 58.

Colonies dense and spherical when young, later elongate and clathrate. Sheath distinct finally dissolving. Cells without pseudovacuoles.

Lat. cell, 6-7·5μ.

Habitat:—Planktonic in a stagnant lake.

*8. *Microcystis pseudofilamentosa* Crow, *Taxon. and variat. genus Micr. in Ceylon, New Phytol.* XXII. p. 64, pl. I. Fig. e, f. 1923. Geitler, *op. cit.*, p. 138, Fig. 61.

Colonies long, narrow, constricted at intervals; sheath not distinct.

Lat. cell, 3-7 μ.

Habitat:—Planktonic in a tank.

Collected by Dr. Hedayetullah, Economic Botanist, Bengal.

9. *Microcystis bengalensis.* sp. nov. (Fig. 2, A & B.)

Colonies irregularly branched, long and broad, varying greatly in form and size, composed of a series of partial colonies which break off and divide again to form compound colonies. Sheath thick, stratified, often distinct. Daughter colonies mostly elongated, irregularly branched like the parent, margin of the colonial mucilage not distinct. Cells spherical with pseudovacuoles.

Lat. cell. 3·5-6 μ.; diam. colon., 30-280 μ.;

Long. colon., 120-800 μ.

Habitat:—Planktonic in a tank.

This species agrees with *Microcystis pseudofilamentosa* Crow. in its elongated form and being composed of series of small colonies which ultimately break off and divide to form compound colonies. It differs from the above named species in its branched habit, much larger colonies, distinct and stratified sheath. The Bengal species also differs from *Microcystis ramosa* Bharadwaja in (1) its bigger size of cells, (2) stratification of colonial sheath and (3) absence of individual sheath of the daughter colonies.

APHANOCAPSA Näg. 1849.

†10. *Aphanocapsa montana* Cramer, in *Wartm. exs.* No. 134. Geitler, *op. ct.*, p. 159. (Fig. 2, C).

Colonies gelatinous, formless, yellowish. Sheath not distinct. Cells spherical or ellipsoidal, single or in pairs.

Lat. cell., 2·5-4 μ.

Habitat:—Attached to *Pithophora* sp. growing on the side of a ditch.

Collected by Prof. G. P. Majumdar of the Presidency College, Calcutta.

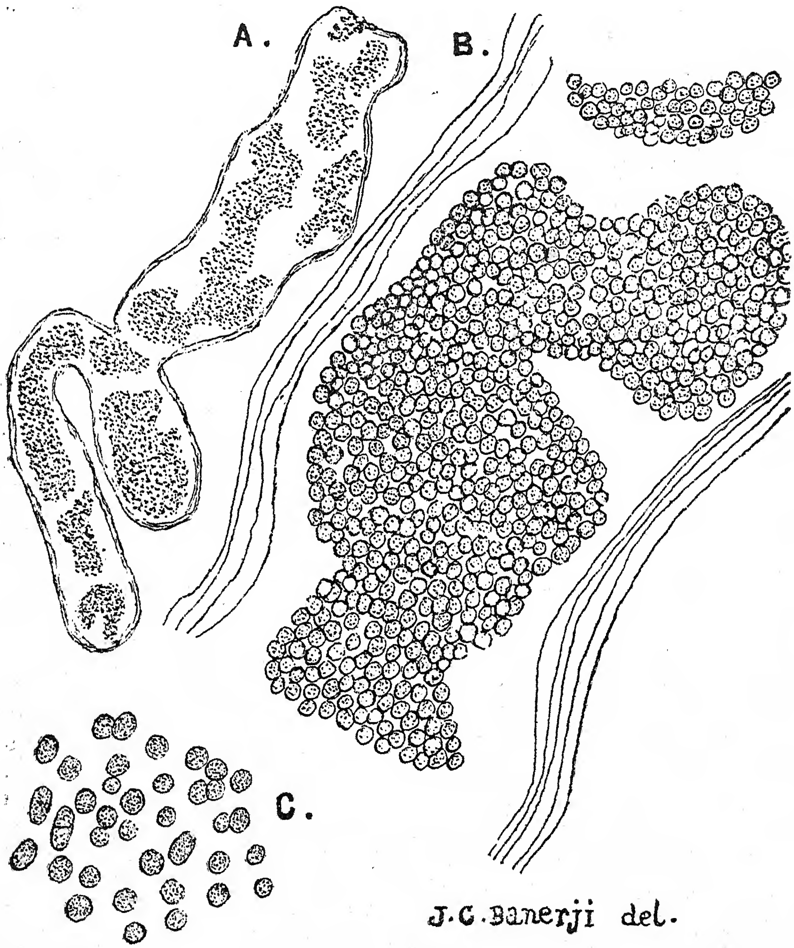

Fig. 2. A. *Microcystis bengalensis* sp. nov. ×65. B. A portion of a colony of the same. ×300. C. *Aphanocapsa montana* colony. ×550.

11. *Aphanocapsa Grevillei* (Hass.) Rabenh. *Fl. Eur. Alg.* II. p. 50, 1865. Geitler, *op. cit.*, p. 159. Fig. 71.

Colonies gelatinous, globose, either forming densely aggregated big patches or small protuberances; sheath often not very distinct.

Lat. cell., 3·5-6 μ.; long. cell., 7-9·5 μ. before division.

Habitat:—Planktonic in inundated paddy-fields and stagnant waters; also forming slimy patches on most soil, etc.

Reported by Brühl and Biswas (10) from filter beds.

APHANOTHECE Näg. 1849.

*12. *Aphanothece stagnina* (spreng.) A. Braun., in Rabenh. *Alg. Eur.* No. 1572. Geitler, *op. cit.*, p. 164. Figs. 72 and 75b.

Colonies gelatinous, flattened, greenish or brownish. Cells oblong-oval, after division often spherical; individual sheath diffluent.

Lat. cell., 4-6·5 μ.; long. cell., 6-11 μ.

Habitat:—Floating in patches in a ditch.

†13. *Aphanothece pallida* (Kütz.) Rabenh., *Krypt. Fl. Sachsen*, p. 76. Geitler, *op. cit.*, p. 171. Fig. 78.

Plant-mass irregular, extensive, flattened and transparent; associated with species of *Anabaena* and *Calothrix*. Cells oblong-elliptical or cylindrical, scattered; sheath thick, lamellose, often confluent.

Lat. cell., 5-8 μ.; with sheath., 10-20 μ;

Long. cell., 6-23μ, with sheath., 11-30μ.

Habitat:—Floating in a shallow pond at Panihati (24 Perghs.)

Collected by Mr. R. M. Datta, Ghose Research Scholar in Botany, C. U. Recorded by Ghose (24) from Lahore.

GLOEOCAPSA Kütz. 1843.

†14. *Gloeocapsa montana* Kütz. *Phyc. gen.* p. 173, No. 1, 1843. Geitler, *op. cit.*, p. 186. Fig. 83d.

Plant-mass thin, blue-green; plants spherical or slightly oblong; sheath thick, lamellose, sometimes peeling off.

Lat. cell., 3-5·5 μ.; with sheath, mostly 6-17 μ, sometimes up to 22 μ.

Habitat:—On a moist brick in the Fern-house of our College.*

Reported by Biswas (7) from the Khasi Hills. Probably brought with the plants collected from the locality and planted in the Fern-house.

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* Biological Departments of the University College of Science and Technology at 35, Baliygange Circular Road, Calcutta.

†15. *Gloeocapsa atrata* (Turp.) Kütz. *Tab. Phyc.* I. Pl. 21, Fig. 4, 1845-49. Geitler, *op. cit.*, p. 188, Fig. 83C.

Plant-mass expanded, pale yellow, crustaceous. Plants spherical; sheath colourless, not stratified.

Lat. cell., 3·5-5 μ.; with sheath, 8-14 μ.

Habitat:—On a damp, perpendicular wall adjacent to a filtered-water tap in our College compound.

Reported by Turner (32) from Northern India, by Ghose (22) from Rangoon and by Bharadwaja (2) from Benares.

†16. *Gloeocapsa gelatinosa* Kütz. *Phyc. gen.* p. 174, 1843. *Tab. Phyc.* Pl. 20. Fig. 6b. Geitler, *op. cit.*, p. 187.

Plant-mass gelatinous, bullose, greenish. Plants globose-oblong; sheath narrow, colourless, sometimes lamellose.

Lat. cell., 2-2·5 μ. with sheath, 6·5-9 μ.

Habitat:—On the side of a cemented drain.

Reported by Ghose (22) from Mergui, Burma.

17. *Gloeocapsa quaternaria* (Bieb.) Kütz. *Tab. Phyc.* I. Pl. XX. Fig. 1, 1845-49. Geitler, *op. cit.*, p. 197, Fig. 91e.

Plant-mass pale green or black, brownish or yellowish, spreading or forming small tubercles. Plants often spherical; sheath narrow, lamellose.

Lat. cell., 3-5μ with sheath, 7-11 μ.

Habitat:—Common on moist sub-äerial habitats.

Reported by Brühl and Biswas (10) from filter-beds and by Ghose (24) from Lahore.

18. *Gloeocapsa rupestris* Kütz. *Tab. Phyc.* I, Pl. XXII, Fig. 2. 1845-49. Geitler, *op. cit.*, p. 194. Figs. 88c, 89.

Plant-mass gelatinous, spreading, pale yellow. Cells spherical or oblong; sheath thick, lamellose, yellowish.

Lat. cell., 6-11 μ. with sheath, 9-20 μ.

Lat. fam. 17-116 μ.

Habitat:—Floating in masses in a shallow pond.

Collected by Mr. R. Datta.

Reported by Prain (30) from the river Hugli and by Ghose (24) from Lahore.

CHROOCOCCUS Näg. 1849.

19. *Chroococcus turgidus* (Kütz.) Näg. *Gatt. einzell Alg.*, p. 46. 1849. Geitler, *op. cit.*, p. 228. Figs. 109b and 110.

Plants spherical or oblong-ellipsoid, mostly solitary or in groups of two or four.

Lat. cell., 10-28 μ. with sheath, 14-35 μ.

Habitat:—Distributed through gelatinous masses of *Aphanocapsa* and *Gloeocapsa*. Also found in association with *Anabaena, Calothrix* and *Microchaete* from aquatic habitats. Common.

20. *Chroococcus minutus* (Kütz.) Näg., *op. cit.,* Geitler, *op. cit.,* 232, Figs. 112a, 113c.

Plants spherical or oblong; sheath not very distinct.

Lat. cell., 4-6 μ. with sheath, 6-10 μ.

Long. cell., 7-10 μ. with sheath, 10-15 μ.

Habitat:—Imbedded in the mucilage of sub-aërial and aquatic Myxophyceae, common.

MERISMOPEDIA Meyen. 1839.

†21. *Merismopedia elegans* A. Braun. in Kütz. *Spec. Alg.* p. 472. Geitler, *op. cit.,* p. 265, Fig. 129e.

Colonies large, flat, rectangular, greenish, composed of 64-1024 cells.

Long. cell., 5-9 μ. Lat. cell., 5-7 μ.

Habitat:—Planktonic in a pond, sparingly associated with *Microcystis aeruginosa,* very rare.

Recorded by Carter (11) from Suket and river Dihang under Rotung at 700 ft.

22. *Merismopedia glauca* (Ehrenb.) Näg. *Gatt. einzell, Alg.,* p. 55. Pl. I.D., Fig. 1, 1849. Geitler. *op. cit.,* p. 264. Fig. 129d.

Colonies small, flat, rectangular, light blue-green, composed of 4-64 cells.

Lat. cell., 3-5 μ.

Habitat:—Planktonic in a pond, sparingly associated with *Microcystis flos-aquae.*

Reported by Turner (32) from Northern India.

VI. Summary and Conclusion.

The analysis of the foregoing results of the preliminary observations on the Myxophyceae of Lower Bengal brings out the following points:

1. Myxophyceae clothe the moist sub-aërial habitats of the locality throughout the year irrespective of any seasonal variations in the climate.

2. There is a progressive development of this group of plants on almost all conceivable sub-aërial habitats with the advent of monsoons. The growth is generally most abundant from the end of July to the middle of October as the temperature, light and moisture conditions, prevailing at the time, favour such abundance.

3. Variations in light also partly influence the growth and distribution of Myxophyceae.

4. *Oscillatoria* appears to dominate the land communities.

5. Relative dryness of the atmosphere and substrata, during the period extending from November till the advent of the next monsoons, particularly cause most marked decrease in the extent and development of the sub-äerial Myxophyceae.

6. The initial conditions of temperature of water and the concentration of its contents may favour or exclude certain planktonic forms irrespective of any other factors.

7. *Microcystis* is the dominant genus, in most of the bigger bodies of water with clean open surface, specially during the spring and summer.

8. Floating, entangled masses of filamentous blue-greens predominate during summer and autumn especially in those pieces of water which are overgrown with suspended and submerged macrophytes.

9. *Spirulina platensis* and *Oscillatoria formosa* were found forming pure scum on the surface of waters very rich in organic contents.

10. Out of the twenty-two species of Chroococcaceae recorded, five are reported for the first time from India, six are new records from Bengal and one is new to science.

In the preceding pages, an attempt has been made to establish the relationship of some of the conspicuous, planktonic blue-green algae to certain factors but the assignments must be taken as quite tentative, because more detailed and prolonged investigations have to be undertaken before the causative variables can be determined with any certainty. The question of competition between the associated plants and animals, along with the question of migration of certain forms within certain pieces of water, is still to be considered.

In conclusion, I take the opportunity to express my indebtedness and gratitude to Prof. S. P. Agharkar for his constant encouragement and kindness in affording facilities; to Prof. Frémy of France for kindly confirming the determinations of a few species and to Mr. K. P. Biswas of Royal Botanic Garden, Calcutta, for his valuable suggestions.

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STUDY OF SOME PHYSICO-CHEMICAL CHANGES IN LEAF MOVEMENTS

BY

R. H. Dastur and D. E. Wadia

Botany Department, Royal Institute of Science, Bombay

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Introduction

Though the mechanism of leaf movements is not properly understood, it is well known that the pad or cushion-like pulvini of the main and secondary petioles are directly concerned in these movements. The curvature of the pulvinus results on the perception of a stimulus, and is probably due to the alteration of turgor in the cells of the pulvinus. Various reasons are given for the loss of turgor on the lower side of the pulvinus (Pfeffer (7), Lepeschkin (4), Blackman and Paine (1) and Sen (8, 9)).

The contraction of the lower half of pulvinus in the case of sensitive plants suggests loss of water, and the loss of water through the living cells cannot occur unless it is preceded by some physico-chemical changes. Similarly, the reabsorption of water by these same cells on recovery must be preceded by a reverse physico-chemical change and that may bring about a dehydration of the protoplasm and consequently of the cells.

Protoplasm is protein in nature and it is a well-known physical phenomenon that colloidal solutions containing protein lose water when they reach their iso-electric point. It is, therefore, possible that on the arrival or the discharge of hormones on account of the stimulus of light or of shock there is a sudden change in the pH value of the cells or in some equivalent characteristic so that the protoplasm or the principal proteins undergo colloidal changes by the alteration of H-ion concentration, and they tend to lose water unequally on the two sides of the pulvinus. We have, therefore, attempted (1) to determine the suction pressure of the cells of the two halves of the pulvinus of different plants, (2) to determine the hydrogen-ion concentration of the reacting tissues and (3) to determine the iso-electric points of the upper and lower halves of the pulvini, stems and leaflets of the same plants.

If the physico-chemical change in the protoplasts of the motor cells is responsible for the loss of turgor and consequent movements of the leaves of the sensitive plants as suggested above, it is likely

that the same cause may be operating in the case of plants which show "sleep" or "photeolic" leaf-movements. It is, therefore, necessary to include such plants in this investigation as well as those plants whose leaves show no movement of any kind.

Investigation

Mimosa pudica Linn. and *Neptunia oleracea* Lour., *Pitheco-lobium saman* Benth, *Pongamia glabra* Vent. and *Erythrina indica* Lam. were selected for investigation.

Determination of the suction pressure.

In explaining the mechanism of curvature, it is supposed that a fall in turgor pressure in the lower half of the pulvinus occurs; but nobody has as yet shown by actual measurement that this is actually the case. It is, therefore, first necessary to determine the turgor-pressure of the cells on the two sides of the pulvinus before and after stimulation. As there is no direct method of measuring the turgor pressure, it is made indirectly by finding out the net suction pressure of the cells.

The suction pressure is the pressure sending water into the cells. It is equal to the difference between the osmotic pressure of the cell-contents and of the external liquid, minus the wall-pressure exerted by the cell-wall against the hydrostatic pressure. In this case it is not necessary to measure the osmotic pressure as the measurement of the suction pressure alone should indicate differences in the hydrostatic pressure. If the loss of water occurs from the cells situated on the lower half of the pulvinus, their suction pressure should be greater than that of the cells on the upper half, in the drooped condition; and if the suction pressure is higher in the lower cells, the hydrostatic pressure is naturally lower than that of the cells situated on the upper side. Thus the fall in the turgor pressure in the cells of the lower side could be determined by noting the differences in the suction pressures of the cells of both the sides of the pulvinus.

The suction pressure is determined according to the method of Molz (5). It should be noted that the strips used contained only the cortical tissue and did not include any part of the conducting tissue. A large number of such determinations were made on the main healthy pulvini of the different leaves from different plants, and the following Table I gives the results of some of these determinations.

The results show very appreciable differences between the values of suction pressure on the two sides of the motor-organ. The difference in the suction pressure between the two sides varies from 2 to 4 atmospheres. The suction pressure of the lower half of the pulvinus is higher than that of the upper half, indicating

that the turgor pressure in the lower half has fallen, and the escape of water is probably the cause of lowering the turgor pressure and increasing the suction pressure on the lower region of the pulvinus, while the suction pressure in the upper half is lower, indicating greater turgidity in that region of the pulvinus.

It was next undertaken to determine the suction pressure in the lower and upper halves of the secondary pulvini of *Pithecolobium saman* Benth. in the day position as well as in the night position (Table I).

TABLE I

Suction pressure in the upper and lower halves of the main pulvinus of *Mimosa pudica,* Linn. and the terminal secondary pulvinus of *Pithecolobium saman,* Benth.

MIMOSA PUDICA, LINN.		*PITHECOLOBIUM SAMAN,* BENTH.			
—		IN DIURNAL POSITION		IN NOCTURNAL POSITION	
S.P. In the upper half. (Atms.)	S.P. In the lower half. (Atms.)	S.P. In the upper half. (Atms.)	S.P. In the lower half. (Atms.)	S.P. In the upper half. (Atms.)	S.P. In the lower half. (Atms.)
12·97	15·71	14·35	14·35	17·09	19·95
14·35	18·49	15·71	15·71	17·09	19·90
13·65	15·71	14·35	14·35	15·71	17·09
12·97	17·09	15·71	15·71	15·71	15·75
12·97	16·43	14·35	14·35	17·09	20·73
12·97	16·43	17·09	17·09	15·71	18·49
13·65	15·71	17·09	17·09	17·79	20·73
12·97	16·43	15·71	15·71	15·71	18·49

The results show that the values of the suction pressure in the lower and the upper halves of the pulvinus are the same during the day when the leaves are fully spread out on the main axis, but during the nocturnal position similar differences in the suction pressure on the two regions of the pulvinus are obtained, as in the case of *Mimosa pudica* Linn.

It may be concluded that the fall in the turgor pressure of the lower side of a pulvinus of a leaf occurs when the movement

is performed, while no fall in the turgor pressure in the lower side of the pulvinus occurs when no movement of any kind is performed. The results also suggest that the fall in turgor is not caused either by the inactivation of the osmotically active substances in the cells or by passing out of the osmotically active substances from the cells of the lower side of the pulvinus, as was suggested by previous workers. If the latter was the case, there should not have been a rise in the suction pressure of the cells of the lower half after the curvature of the pulvinus. The loss of water, therefore, is due to some other physico-chemical changes in the protoplasm, as may be inferred from the observations recorded below.

The pulvinus of *Erythrina indica* Lam. shows no leaf movements; it was, therefore, undertaken to determine the suction pressure of the two sides of the *pulvinus* (Table II).

TABLE II

Suction pressure in the upper and lower halves of the secondary pulvinus of *Erythrina indica* Lam.

In diurnal position.		In nocturnal position.	
S. P. In the upper half.	S. P. In the lower half.	S. P. In the upper half.	S. P. In the lower half.
(Atms.)	(Atms.)	(Atms.)	(Atms.)
15·71	15·71	17·09	17·09
15·71	15·71	18·49	18·49
17·09	17·09	18·49	18·49
15·71	15·71	19·95	19·95
18·49	18·49	19·95	19·95
17·09	17·09	18·49	18·49
17·09	17·09	17·09	17·09
18·49	18·49	18·49	18·49

The results show no differences in the value of the suction pressure of the upper and the lower halves of the pulvinus of *Erythrina indica* Lam. both in the diurnal and in the nocturnal positions.

Determination of the I. E. P.

Pearsall and Ewing (6) have suggested a method of determining the apparent iso-electric point of plant tissues by studying the diffusion of chlorine-ions from living tissues kept in solutions of different hydrogen-ion concentration. The pH of the external solution in which no diffusion of the chlorine-ions occurred in either direction was found to correspond with the iso-electric point of the chief protein present in the plant tissue. As this method is found to be most suitable for the purpose of this investigation it was decided to adopt it.

The iso-electric points of the proteins of the leaflets, stem and both the upper and the lower halves of the main or secondary pulvini, as the case may be, were determined. The value of the iso-electric point of each tissue is the mean of the three determinations (Table III).

TABLE III.

I. E. P.'s of the leaflets, stem, pulvinus and the upper and lower halves of the pulvinus in the plants showing leaf movements and in the plants showing no leaf movements.

—	Stem.	Leaflets.	Pulvinus.	Upper half of pulvinus.	Lower half of pulvinus.	Difference between the upper and lower halves.
Mimosa pudica Linn. ..	4·18	4·27	4·32	4·49	4·23	+0·26
Neptunia oleracea Lour.	4·10	4·15	4·28	4·38	4·13	+0·25
Pithecolobium saman Benth (Day position).	4·17	4·23	4·27	4·32	4·17	+0·15
Pithecolobium saman Benth (Night position).	4·17	4·25	4·28	4·37	4·20	+0·17
Pongamia glabra Vent. (Day position). ..	4·32	4·37	4·32	4·27	4·32	-0·05
Pongamia glabra Vent. (Night position). ..	4·33	4·37	4·33	4·30	4·33	-0·03
Erythrina indica Lam. (Day position). ..	4·22	4·27	4·22	4·22	4·20	+0·02
Erythrina indica Lam. (Night position). ..	4·23	4·30	4·22	4·22	4·23	-0·01

The variations in chlorine loss observed in this work were larger than those measured by Pearsall and Ewing (6) and the apparent

iso-electric points could be determined to within pH 0·06 in replicate determinations. The means of three determinations should be somewhat more accurate.

These results indicate that the apparent iso-electric point of the tissues of the upper half of the pulvinus in plants showing leaf movements is higher than that of the tissues of the lower half. These differences in the apparent iso-electric points of the tissues of the upper and lower halves of the pulvini are greater in the species of *Mimosa* and *Neptunia* than in *Pithecolobium saman*, Benth. No such differences are noticed in the case of the other two species.

Determination of the pH value

The H-ion concentration of the tissues of the leaflets, stem, petiole, rachis and upper and lower halves of the main pulvinus of these plants are determined by the colorimetric method described by Clarke (2), using a constant amount of tissue ground up in a constant amount of water. The results given below in Table IV are the averages of five determinations in each case.

TABLE IV.

The pH values of the tissues of the different parts of plants performing leaf movements and performing no leaf movements.

—	Stem.	Leaf.	Pulvinus.	Upper half of pulvinus.	Lower half of pulvinus.	Difference between the upper and lower halves.
Mimosa pudica Linn. (Drooped position). ..	5·76	5·86	6·04	6·24	5·94	+0·30
Neptunia oleracea Lour. (Drooped position). ..	5·25	5·32	5·46	5·64	5·32	+0·32
Pithecolobium saman Benth (Day position).	5·60	5·68	5·70	5·72	5·72	0·00
Pithecolobium saman Benth (Night position).	5·76	5·62	5·98	6·10	5·84	+0·26
Erythrina indica Lam. (Day position). ..	5·60	5·88	5·70	5·70	5·70	0·00
Erythrina indica Lam. (Night position). ..	5·85	5·62	5·87	5·87	5·87	0·00
Pongamia glabra Vent. (Day position). ..	5·42	5·60	5·42	5·42	5·42	0·00
Pongamia glabra Vent. (Night position). ..	5·55	5·42	5·55	5·55	5·55	0·00

The pH of the upper half of the pulvinus is higher than that of the lower in the drooped position of the petioles of *Mimosa pudica* Linn. and *Neptunia oleracea* Lour, and in the night position of the leaf in the case of *Pithecolobium Saman* Benth. In the latter there is no difference in pH of the upper and the lower halves of the responding secondary pulvinus in the day position when it is not in the drooped condition. Similarly there are no differences in the pH in either the day or the night positions in the remaining two species.

Discussion

The determinations of the suction pressure have indicated that the turgor pressure of the cells of the lower half falls when the curvature of the pulvinus occurs. The results obtained with the leaves of *Pithecolobium saman* Benth. also support the same conclusion. The measurements of the hydrogen-ion concentrations of the cells in the two regions of the pulvinus of plants performing leaf movement show a difference in the pH values of the cells of the upper and lower halves of the responding organs. The pH value of the upper half is always higher than that of the lower one in the case of *Mimosa pudica* Linn. and *Neptunia oleracea* Lour. In the case of secondary pulvinus of *Pithecolobium saman* Benth. there is no difference in the pH on the two sides in the day position when the pulvinus stands erect, but the difference is noticed in the pH of tissues on the two sides when the curvature of the pulvinus occurs. This difference is not found in the case of plants like *Pongamia glabra* Vent. and *Erythrina indica* Lam.

The apparent iso-electric points of the proteins of the cells on the upper halves of the pulvinus of plants showing leaf movements is different from that of the lower half of the same pulvinus. In *Pithecolobium saman* Benth. the differences in the apparent I. E. P. are found both at day time as well as at night before and after curvature has taken place, indicating that the difference in the apparent I. E. P. of the proteins of the two halves exists even before the leaves perform the photeolic movement. No such difference in the apparent iso-electric points of the proteins in the two sides of the pulvinus is noticed in *Pongamia glabra* Vent. and *Erythrina indica* Lam.

It is not easy to assume that the differences in the iso-electric points of the proteins of the cells of the upper and lower halves of the responding pulvinus are due to differences in the nature of the proteins of the cells on the two sides or they are due to changes in the gross chemical composition. This difference in the apparent iso-electric points of the tissue of the two sides may be due to the differences in their ionic concentration. The fact that the upper half of the pulvinus is iso-electric in less acid solution than the lower half may indicate a difference in the salt concentration of the cells on the two sides.

The differences in the apparent iso-electric points on the upper and lower sides suggest that the diffusion of chlorine-ions (anions) occurs less easily on the lower side than on the upper side of the pulvinus and therefore the tissue on the lower side is more electro-positive. The pH measurements of the tissues of the two sides of the pulvinus show that the lower side is more acidic than the upper side and so the tissue of the lower side is more electro-positive as the proteins are not likely to alter in their chemical composition. This being the case, the lower side may be nearer to its iso-electric point than the upper side of the pulvinus. It is a well known physical phenomenon that colloidal solutions tend to lose water when they are nearer their iso-electric points. They also tend to lose water at other hydrogen-ion concentrations when the proteins show minimum swelling and least viscosity. It is also possible that the arrival of hormones (or travelling ions) on the lower side may possibly alter the charge on the protein and may also bring the proteins nearer their iso-electric points. Hence the lower side begins to lose water more readily than the upper side of the pulvinus as the former is either nearer its iso-electric point than the latter or it is brought nearer the iso-electric point on the arrival of the travelling ions or hormones. The loss of water brings about the concentration of salts on the lower side, thus increasing the suction pressure, as shown by the suction pressure measurements. Thus the difference in the turgor pressures of the two sides of the pulvinus is produced, resulting in its curvature.

Summary

In order to understand the mechanism of leaf movements the turgor pressure, the apparent iso-electric point and the pH value of the tissues of the upper and lower halves of the responding pulvinus of *Mimosa pudica* Linn., *Neptunia oleracea* Lour. and *Pithecolobium saman* Benth. were determined. Similar determinations were made for comparison in two other species which do not show leaf movements.

The turgor pressure was indirectly determined by measuring the suction pressure. The lower side of the pulvinus in the drooped position showed a higher suction pressure and consequently a lesser turgor pressure than the upper side. Similarly the tissues of the lower half of the pulvinus were apparently iso-electric in more acid solutions than those of the upper half of the pulvinus. The pH value determinations show that the lower half of the pulvinus is more acid than the upper half.

The results suggest that the tissue on the lower half of the pulvinus is more electro-positive and may be nearer its iso-electric point than the upper half. It, therefore, should lose water more readily than the upper half. The loss of water brings about a loss in turgidity and an increase in the salt concentration, as shown by the suction pressure measurements.

No such differences in the physico-chemical properties of the tissues of the two sides of the pulvinus are noticed in plants that perform no leaf movements.

Acknowledgment

We have to offer our cordial thanks to Dr. W. H. Pearsall of the Leeds University for a very helpful suggestion in the interpretation of the results. We have also to thank the Wilson College authorities, Bombay, for providing all facilities to the Junior Author during the progress of this investigation.

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CHARACIOSIPHON, A NEW MEMBER OF THE CHLOROPHYCEAE

Preliminary Note

BY

M. O. P. IYENGAR, M.A., PH.D., (LONDON), F.L.S.

Professor of Botany, University of Madras

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This alga was found growing in clusters on tiny stones and pebbles in the bed of a shallow stream, in three to four inches of water at Vaiyampatti near Trichinopoly in South India.* The alga is up to 1 cm. long and about 0·5-1 mm. broad. It is more or less cylindrical and long and, when fully grown, is somewhat club-shaped and broader at the upper end and gradually narrowed down to its base where it is attached to the substratum (pl. XXIII, 1, figs. 1, 2, 7). It is bright green in colour when living.

The alga at first sight looked like a large coenocyte with numerous disc-shaped parietal chloroplasts. But a careful examination of a large number of living specimens and also stained microtome preparations of the alga showed that what looked at first sight like separate chloroplasts were really discrete lumps of protoplasts each containing inside a large stellate chloroplast (figs. 5, 6) on the outer side and a small nucleus towards its inner side below the chloroplast. A single pyrenoid is imbedded in the chloroplast. The product of assimilation is starch. In the living alga two to five contractile vacuoles are found actively working in the cytoplasm of each protoplast. No eye-spot could be detected in any of the protoplasts. Thus each individual protoplast possessed all the characteristics of a single uninucleate green cell, only it did not possess a cell wall.

Though the several protoplasts formed discrete units and were quite separate from one another, careful examination showed that they were united with one another by means of delicate protoplasmic strands not unlike those of some species of

*I am indebted to Rev. Mr. A. Rapinat, S.J., Professor of Botany, St. Joseph's College, Trichinopoly, for kindly placing his formalin material of the alga at my disposal and for directing me to the locality where the alga was growing.

Volvox (fig. 4, pl. XXIII, 3, 4). The protoplasts in the young plants and the basal portions of the older plants are quite separate from one another, and are more or less round in surface view and somewhat elongated elliptic in edge view (figs. 5, 10). They are more numerous and placed closer together towards the upper part of the thallus, and, in the topmost portions, they are extremely crowded and become highly angular by mutual pressure and present a parenchymatous appearance (fig. 3). They are here pentagonal to hexagonal in surface view and somewhat rounded-quadrate to oblong in edge view (fig. 6). But even the most careful examination does not reveal the presence of a wall round any of the protoplasts. It is again very interesting to note that, though these protoplasts were pressed against one another very closely, their margins did not show any signs of fusing with those of the neighbouring protoplasts. The several protoplasts retained their individuality throughout and remained quite separate from one another.

The living material was brought from Vaiyampatti to Madras and kept growing in the Laboratory for some time. Several stages of the development of the alga were followed in some detail.

Both asexual and sexual reproduction were observed. During asexual reproduction the contents of the thallus become converted into a mass of biciliated zoospores, which escape by a rupture of the apical portion of the thallus. These, after swarming for some time, settle down and grow into new plants. Biciliated gametes also were observed. These resembled the zoospores and fused in pairs. The development of the zygotes could not be followed.

In the young plant in its unicellular condition are present a stellate chloroplast with one pyrenoid imbedded in it and many contractile vacuoles. At its basal end two thin thread-like structures traverse downwards from the protoplast through the thick wall. These are really the persisting old basal portions of the cilia of the zoospore when it settled down. Such persisting ciliary stalks are seen in *Characiochloris* Pascher [1]. Moreover, *Characiochloris* also possesses a stellate chloroplast with a pyrenoid imbedded in it and many contractile vacuoles. The present alga in its unicellular condition closely resembles the full grown individuals of *Characiochloris.*

The structure of the thallus of this alga is very extraordinary and is not known in any other alga. The thallus cannot be called a coenocyte, since we do not have a continuous multinucleate protoplast. On the other hand, the several individual unwalled protoplasts are quite distinct from one another and possess a single

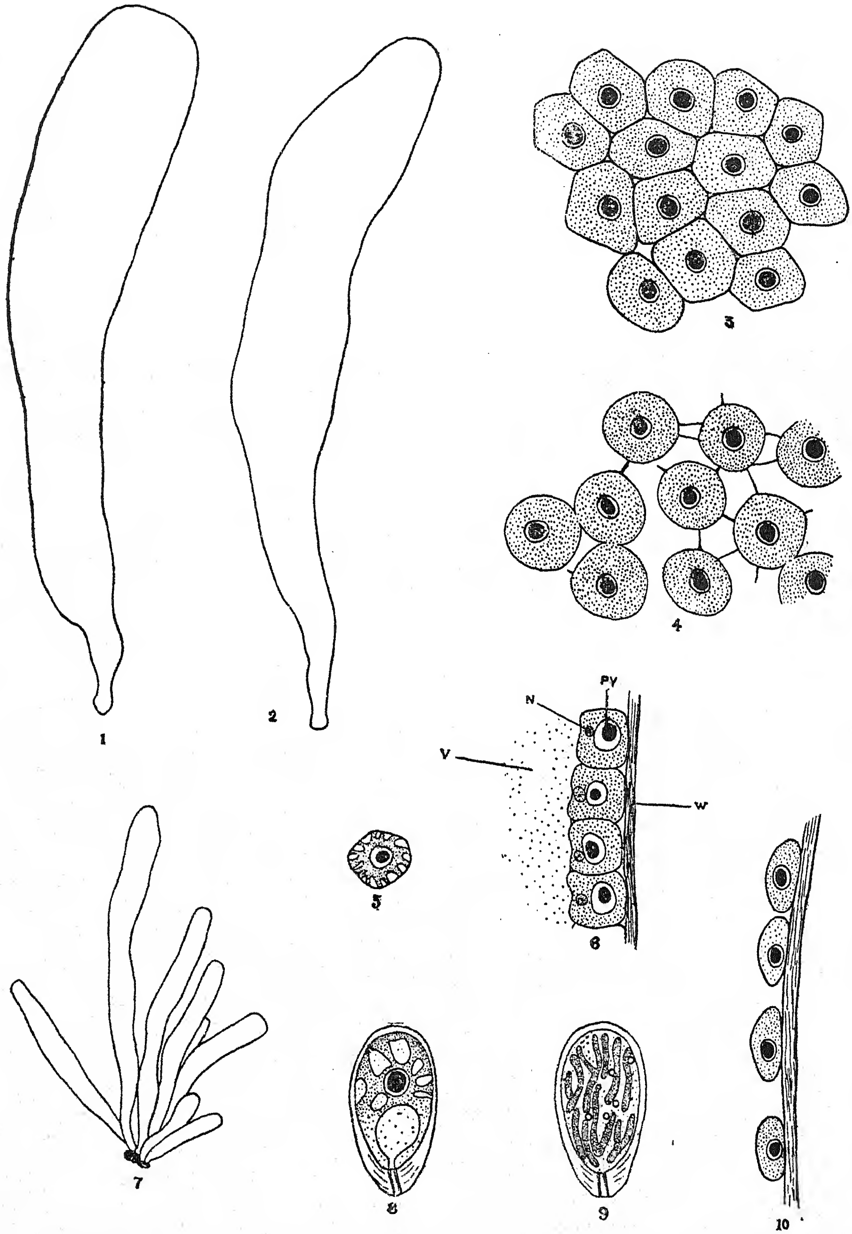
(1) Pascher, A. (1927). Süsswasserflora Deutschlands, etc., Heft 4. Volvocales-Phytomonadinae, pp. 485-7. Korshikov, A. A. (1932) Studies in Vacuolatae I. Archiv für Protistenkunde, Bd. 78, pp. 557-62.

nucleus each and so must be considered as separate cells though inside a common envelope. The presence of contractile vacuoles in each of the individual protoplasts is another strong point for considering them as separate cells and not parts of a common coenocytic structure. Again the fact that the protoplasts retain their individuality even in the uppermost portions of the thallus where they are placed very closely pressing against one another suggests again that we are dealing with separate cell-units and not merely parts of a coenocytic structure.

Now, if the delicate protoplasmic connections between the several protoplasts should be considered as equal to the intercellular connecting strands seen in *Volvox* then the separate protoplasts should be considered as separate unwalled cells inside a common envelope. If, on the other hand, this view should not be accepted, then we must consider the several protoplasts with their protoplasmic connections as parts of a huge coenocytic structure. If the latter view should be preferred, then we are dealing with a very extraordinary type of coenocytic structure in which the protoplast has become compacted into several discrete cell-like units connected with one another by delicate protoplasmic strands, each unit having a single chloroplast, a nucleus and 2-5 contractile vacuoles. Such a coenocytic structure has not been known so far in any other alga. This therefore is a new type of structure coming between a normal coenocyte and a multicellular structure. Since, owing to the presence of a common envelope and the absence of walls round the individual protoplasts, it stands nearer to a coenocytic than to a multicellular structure—though it must be admitted that there are sufficient grounds for considering it a multicellular structure of an extraordinary type—a new name, "protocoenocyte" may be given for this type of structure. It must however be pointed out that the difference between a coenocyte and a multicellular structure is only very slight. Fritsch[1] states that coenocytes "are best interpreted as multicellular structures lacking the usual septation". Here, in this alga, we have a concrete case to illustrate Fritsch's interpretation of a coenocyte.

The systematic position of the alga is not quite clear. The fact that contractile vacuoles are present in the protoplasts suggests that it must be a very primitive form. The alga in its general shape shows some resemblance to *Codiolum* and *Protosiphon,* but, in the structure of its protoplast, it entirely differs from them. Since, as pointed out already, the young unicellular plants show a certain amount of resemblance to the individual plants of *Characiochloris* Pascher, it is very probable that the alga has been derived from some unicellular ancestor resembling *Characiochloris*. The alga may

(1) West, G. S. and Fritsch, F. E., British Fresh Water Algae, 1927, p. 31.



Figs. 1-10. *Characiosiphon rivularis* sp. et gen. nov. Figs. 1, 2. Two full grown plants. Fig. 3. Protoplasts in the upper parts of the thallus angular through mutual pressure. Fig. 4. Protoplasts from lower part of

be placed in a new genus by name *Characiosiphon* in a separate family, Characiosiphonaceæ, close to the family, Characiae, and may be called *Characiosiphon rivularis* sp. nov.

Description

Characiosiphon gen. nov.

Thallus elongated, cylindrical and somewhat clavate when old, consisting of an outer firm common membrane closely investing a large number of separate naked cell-like protoplasts arranged in a single layer immediately below it and having a large hollow space filled with sap in the centre; the protoplasts connected with one another by protoplasmic processes; each protoplast having on the outer side a more or less stellate chloroplast with a large pyrenoid embedded in it and a single nucleus below the chloroplast close to the central hollow space; two or more contractile vacuoles regularly working in each protoplast in the living alga; eye-spot absent; asexual reproduction by means of biciliated zoospores which escape outside through the rupture of the thallus; sexual reproduction by means of biciliated gametes which fuse in pairs to form a zygote; development of the zygote not known.

Characiosiphon rivularis sp. nov.

General characters same as those of the genus. Thallus up to 1 cm. long and 0·5-1 mm. broad; apex of the thallus broadly rounded to obtusely conical; common cell-wall thick and lamellated; protoplasts in the lower part of the thallus placed somewhat separately from one another and more or less round to ellipsoid in surface view; protoplasts in the uppermost parts of the thallus placed more compactly and angular through mutual pressure and pentagonal or hexagonal in surface view; protoplasts 13—15 μ in diameter.

Hab. Plants growing in clusters on small pebbles and stones in a shallow stream at Vaiyampatti, near Trichinopoly, South India. Collected by A. Rapinat.

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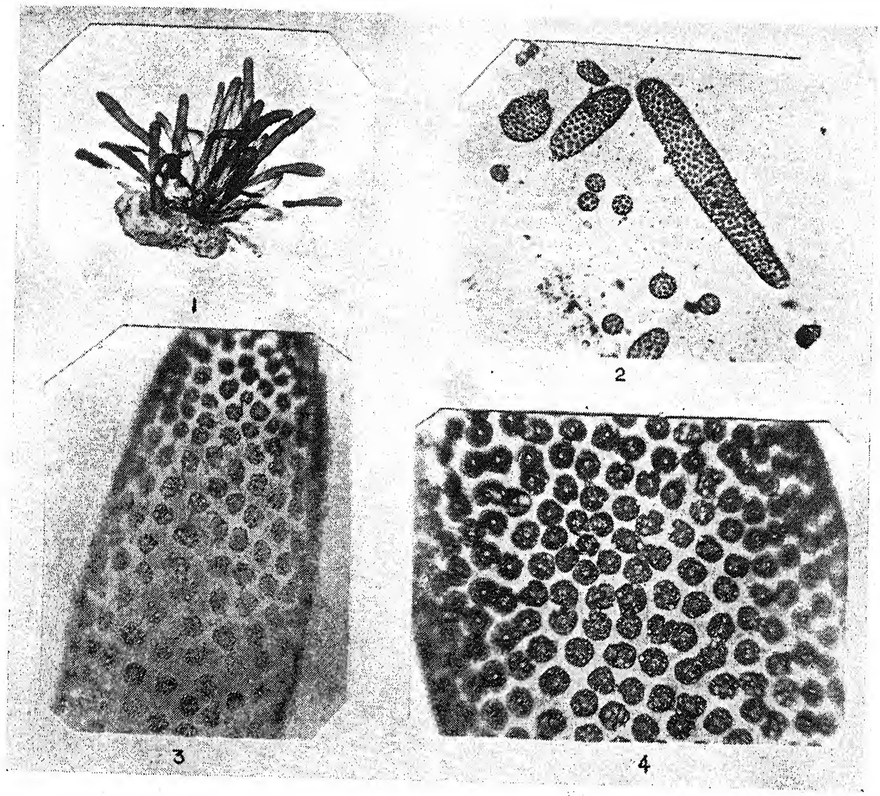
the thallus lying separate and showing protoplasmic connections. Fig. 5. A single protoplast showing stellate chloroplast and pyrenoid. Fig. 6. Portion of a microtome section of the thallus showing position of the nucleus and of the pyrenoid. Fig. 7. A cluster of young plants. Fig. 8. Young unicellular plant showing stellate chloroplast and the pyrenoid and basal ciliary strands. Fig. 9. The same in surface view showing five contractile vacuoles and the terminal ends of the stellate chloroplast. Fig. 10. Edge view of the cells near the lower portion of the thallus. *w*, wall of thallus; *py*, pyrenoid; *n*, nucleus; *v*, central vacuole of the thallus. Figs. 1, 2 and 7, X 15: the rest, X 700.

Explanation of Plate XXIII

Characiosiphon rivularis sp. nov.

1. A cluster of plants growing on a small stone. X 2.
2. Photomicrograph of young plants grown in cultures showing various stages of development. X 72.
3. Photomicrograph of a young plant showing the separate protoplasts in surface view. Protoplasmic connections are seen between many of the protoplasts. Contractile vacuoles can be seen in several protoplasts. X 270.
4. Photomicrograph of a portion of an older plant showing the protoplasts placed more compactly. X 270.



M. O. P. IYENGAR—*CHARACIOSIPHON RIVULARIS* sp. et gen. nov.

WEGENER'S THEORY OF CONTINENTAL DRIFT IN THE LIGHT OF PALAEOBOTANICAL EVIDENCE

BY

B. SAHNI, SC.D., F.G.S., F.R.S.

Professor of Botany, Lucknow University

(With three figures in the text)

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Contents

Introduction

At the forthcoming session of the Indian Science Congress, to be held in January 1937 at Hyderabad-Deccan, there is to be a joint meeting of the sections of geology, botany and zoology with a view to discuss Wegener's theory of continental drift. Although this subject has been widely discussed in scientific circles during the last

ten or twelve years it still claims the attention of men of science all over the world. This must be due, partly at least, to the regional appeal of much of the evidence, apart from the intrinsic interest of this many-sided problem. In the following paragraphs the writer has attempted to give, in as few words as possible, an advance summary of the palaeobotanical evidence with special reference to India and the adjoining countries.

The Evidence

I. Palaeozoic.

From a broad survey of the Late Palaeozoic botanical provinces two striking facts emerge *(see Sahni 1935, pp. 385–386, figs. 1–3)*[1]:

(1) some countries with closely related floras lie on the opposite sides of the biggest oceans of the globe (Fig. 1);

(2) others with very distinct floras, for example, the Gondwana province of India-Australia and the *Gigantopteris* province of China-Sumatra, lie dovetailed with each other (Fig. 3).

Can we explain these facts without the aid of the drift theory?

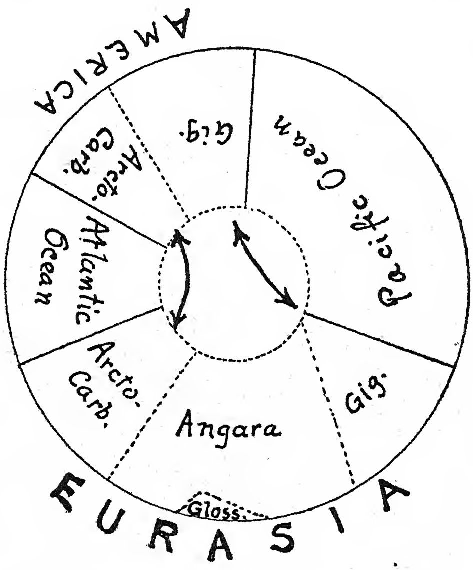

Fig. 1.

(a) Gondwanaland.

The distribution of the early Gondwana glaciation has always impressed me as a most weighty argument in support of Wegener. But speaking only as a palaeobotanist, I confess that my position ten years ago was that of an agnostic. It then occurred to me that it might help us to choose between the drift theory and the old

[1] I am indebted to the authorities of *Current Science* for permission to reproduce text-figs. 1-3 from the blocks kindly lent by them.

theory of land-bridges if we could compare in detail the homotaxial floras of those districts which now lie on the opposite coasts of oceans, but which in Wegener's Pangaea lay in contact with each other, possibly even forming parts of the same fresh-water basins. For convenience we will call these pairs of corresponding points on the opposing coasts by the name "homoposts". If a district A on the east coast of South America was a homopost of A′ on the west coast of Africa, we might expect to find, if not an identity, at least a much greater affinity between their floras than we would if A and A′ had merely been connected by a bridge about two thousand miles long. To facilitate these comparisons all the older southern fossil floras were tabulated in parallel columns *(Sahni 1926,* Charts I–IV). But it was found that, apart from other difficulties, our knowledge of homopositous floras was too unequal to allow any really helpful comparisons. We still lack data from the critical areas either on the one side or on the other *(loc. cit. pp. 232–233).* Du Toit *(1927)* has, it is true, made an illuminating comparison of the geological features of the South African and South American coasts. This comparison has lent strong support to Wegener's theory. But from the palaeobotanical point of view the position both here and in other parts of Gondwanaland is much the same as it was ten years ago.

(b) The Glossopteris and Gigantopteris provinces.

We might, however, attack the problem from another angle. We might consider the present geographical relations of two contemporaneous but very unlike floras: the *Glossopteris* flora of Indo-Australia and the *Gigantopteris* flora of Sino-Sumatra.

(i) *Floristic contrast.*—The *Glossopteris* flora is well known for its distinctive character and distribution. It has not much in common with the *Gigantopteris* flora. Speaking of the Upper Palaeozoic flora of Central Shansi, from where the latter flora is best known, Halle *(1927)* remarks that "it is impossible to point to a single species which is unquestionably identical with a member of the *Glossopteris* flora" *(p. 289)* . . . . . . "it is related to the contemporaneous floras of both Europe and North America in much the same manner as the latter are related to each other" *(p. 279).* According to Jongmans and Gothan *(1935, p. 185)* the Sumatra flora (which they regard as pre-Permian and therefore slightly older than that of Shansi) is even more European in character. These authors are even more emphatic than Halle in pointing out the contrast with the Gondwana flora.

A few points of resemblance between members of the two floras have been discussed by all these palaeobotanists, by Kawasaki *(1927, 1931)* who has described the *Gigantopteris* flora in Korea, and by others. In recent years several reports have been published of the sporadic occurrence of members of the *Glossopteris* flora in association with *Gigantopteris* in parts of Indo-China *(Fromaget*

1934 a, pp. 110, 140, 141, 157). Fritel even reported a Permo-Triassic Gondwana flora from Central Shansi *(see Halle 1927, pp. 288–289).* So far as I know, none of these reports have been substantiated by descriptions or figures. It would not be surprising —although it would no doubt be an interesting discovery—to find that occasionally there was an intermingling of the two floras in the Far East. But even after making a liberal allowance for these reports it will be agreed that the two floras, taken as a whole, are very distinct: they must have been evolved on separate continents, though it appears that some means of intermigration was possible in the later phases *(vide infra).*

(ii) *Climatic contrast.*—This floristic contrast is so striking as by itself to raise the suspicion that the two floras, one essentially northern, the other southern, must have lived in different climates. Indeed the current view is that the *Glossopteris* flora was probably evolved in a temperate climate on a continent just emerged from glaciation, the *Gigantopteris* flora in a warmer climate analogous to that of the European coal measures. The view that the *Gigantopteris* flora lived in a climate essentially similar to that of the European coal measures is suggested not only by the strong affinities between these floras but also by the independent evidence of the lithological character of the Upper Shihhotze Series in Shansi. Dr. E. Norin's chemical studies of these beds tend to show that they were deposited in a damp tropical climate *(Norin, 1924; see Halle, 1927, pp. 11–12, 291–292).* The arguments usually advanced in support of moist tropical conditions during the coal measure period in Europe are well known *(see Seward 1933, pp. 253ff).* The frequency with which that Palaeozoic tree-fern[1] *Psaronius,* so common in the Permian forests of Central Europe, is seen to bear epiphytic growths among its aerial roots, may be cited as a further indication of a "luxuriant vegetation comparable to the tropical forest of the present day" *(Sahni 1931, p. 270).*

This brief statement regarding the climatic conditions governing the two floras may sound more like an assertion than a conclusion drawn from evidence, particularly at a time when a recent more critical examination of the evidence has threatened to shake what little faith we had in the climatological value of fossil plants. But on the general question of the climatic contrast between the northern and southern floras, taken as a whole, even Professor Sir A. C. Seward, to whom this cautious attitude is largely due, and who has discussed the whole evidence in detail, agrees that *"the climate of Gondwanaland was doubtless comparatively cold well into the Permian period and much less genial than that of the northern continent" (Seward 1933, p. 258).*

[1] The word tree-fern is here used in a loose sense: as I have elsewhere suggested (*Sahni 1934*) there is no certainty that this genus, although so completely fern-like in its vegetative anatomy, was a true fern. Darrah has recently expressed a similar doubt.

For our present purpose this should suffice. If we agree that the *Glossopteris* flora of India and Australia must have flourished in a climate distinct from that of the Sino-Sumatran province, is it possible to believe that these two regions, dovetailed with each other as we now find them on the map, and covering so much of the same latitudes, have always occupied their present geographical positions? This is the crux of the problem.

(iii) *Drift the only rational solution.* I see no escape from the conclusion that the two provinces originally lay far apart, north and south of the Tethys, and have since drifted towards each other. This conclusion, already foreshadowed by the important work of Professor Halle *(1927, pp. 280–290)*, has been supported Fromaget *(1934)* and the present writer *(Sahni 1935, 1935a)*. Jongmans *(1935, p. 242)* has also been led to conclude that the relations of the Sumatra flora cannot be explained without the aid of the drift theory.

I may be allowed to quote here from an abstract (written in April 1935) of a paper read at Amsterdam. "The proximity of the

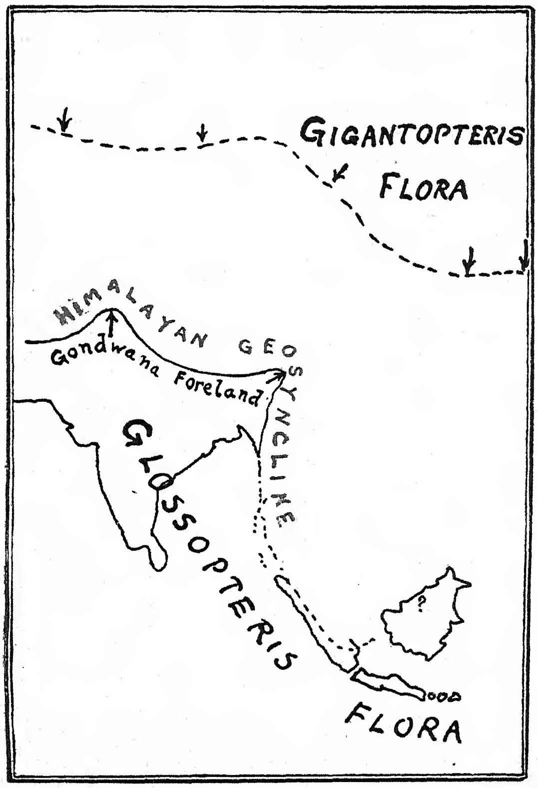

Fig. 2.

western outposts of the *Gigantopteris* flora in Szechuan and Yunnan,

to the Gondwanas in the E. Himalayas and Bengal, and the southern extension of this flora into Sumatra *(Jongmans, Gothan, Posthumus)* like a wedge driven into Gondwanaland, are facts demanding explanation. Probably *(Halle 1927)* the two botanical provinces were separated by an extension of the Himalayan geosyncline which later became folded into the longitudinal mountain belt in Burma. It is difficult to resist the suggestion that the sharp southward bend of the Assam Himalayas and their continuation in a meridional direction through Burma is only an eastern counterpart of the same phenomena of syntaxis which Wadia *(1931)* has so ably elucidated in the N.-W. Himalayas. Thus in the east, as in the west, the Himalayan geosyncline has probably been 'bent round a triangular promontory of the Indian peninsular horst'. The great belt of mountains which forms our landward border is therefore a region of very special interest both from the tectonic and from the plantgeographical points of view" *(Sahni 1935, pp. 246–247).*

(iv) *The Assam syntaxis of the Himalayas.*—The way in which the *Gigantopteris* province probably moved SW-wards to meet the Indo-Australian mass presumably drifting NE, was described in my brief paper on Permo-Carboniferous life provinces, published in December of last year *(1935, pp. 388–389, figs. 2, 3).* Sumatra may be regarded as having formed the spearhead of advance, with the Assam promontory of Gondwanaland serving as a resistant pivot round which the crumpled sediments of the intervening ocean were bent into a sharp angle, marking the sudden southward deflection in the trend of the Himalayan range (Fig. 3). Pending a geological confirmation I had tentatively compared this angle with the similar though less pronounced syntaxial angle in Kashmir, which was attributed by Wadia *(1931)* to the resistance offered by the Kashmir promontory of Gondwanaland to horizontal forces acting from the north. Since then Mr. Wadia *(1936)* has actually supported this view with a variety of evidence from different sides, with the result that a suspicion originally based solely upon palaeobotanical considerations has been placed upon a respectable geological footing, though it will still need to be finally proved by structural evidence in the field.

(v) *Extended definition of the Himalayas.*—The support thus received for the idea of an Assam syntaxis, compared with that demonstrated by Wadia in NW Kashmir, has brought with it the acceptance of an extended definition of the Himalayas, as a series of festoon-like loops stretching from Hazara in the NW as far as the Malay archipelago in the SE *(Sahni 1935 a, figs. 2, 3, pp. 388–389).* The exact trend of the line in its extreme SE loop can only be determined after further exploration has shown the relative distribution of the two floras in the archipelago. The reported occurrences of *Glossopteris* in NW Borneo *(Tenison-Woods 1885)* and southern New Guinea *(Geogr. Journ. 38: 485, 1911)* still await confirmation.

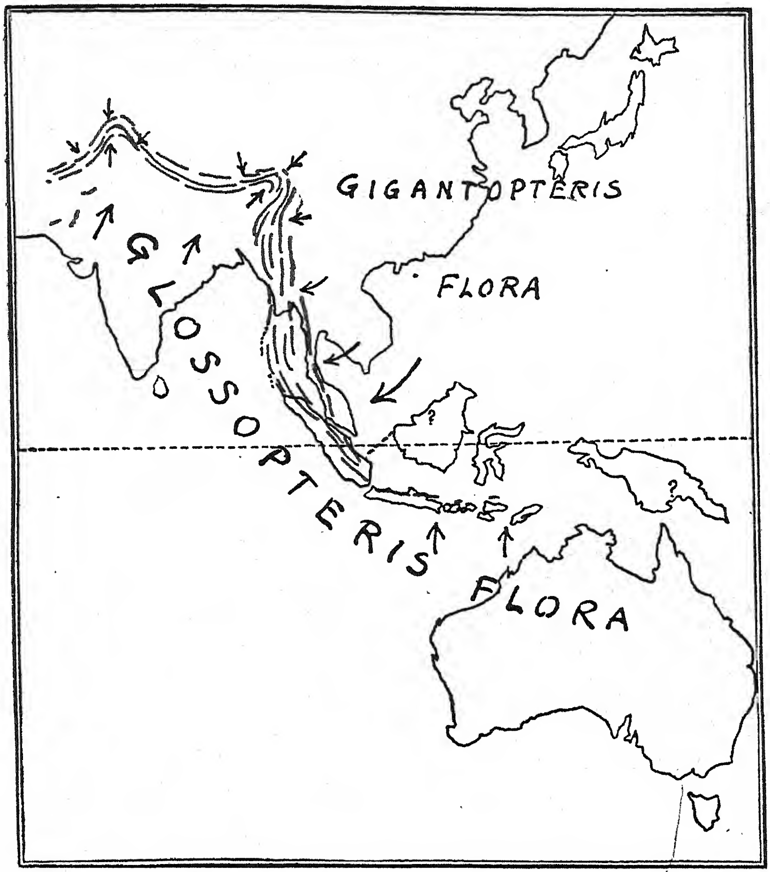

Fig. 3.

(vi) *The nature, extent and position of the barrier between the Gigantopteris province and Gondwanaland.*—If the geographical relations between the two floras were as suggested above, it is clear that we cannot conceive of an *eastward* continuation of the Himalayas from the NE corner of India right across China to the Pacific coast, as Kingdon Ward *(1935 and earlier papers)* believes.

The argument (which, on the evidence of so competent an authority as Captain Ward, we may safely accept as a fact) that the modern flora of the E. Himalayas is more akin to that of the mountains in W. China than to that of the meridional ranges in Burma *(Ward 1935)* is of little weight in the present connection. The mountains of W. China, now adjoining the E. Himalayas and lying on the same latitudes, may well be expected to have acquired a similar flora during the late Tertiary and Pleistocene periods.

The theory now advocated by Ward, following Kropotkin and Gregory, demands the existence of marine strata of the Himalayan facies in an east-west line from NE Assam across the greater part, if not the whole, of the width of China. Apparently this botanist is not satisfied with a mere tongue-like NE projection of the syntaxial angle in Assam, comparable with that in the region of Nanga Parbat in the Kashmir syntaxis *(see Wadia 1936, pp. 68–69, Note by Editor)*. But, so far as we know, there is no evidence whatever of the extension of the Himalayan geosyncline into that Far Eastern region which, from all available accounts, was a land area inhabited by the *Gigantopteris* flora. If the Himalayan sea extended eastwards from Assam, instead of southwards as most geologists agree, then it would be even more difficult to account for the occurrence, to the south of that barrier, of a Carboniferous or Permian flora including not only *Gigantopteris* and other types characteristic of the floras in Shansi and Korea (which lay well to the north of the supposed Chinese Himalayas) but also a strong contingent of European coal measure species *(Edwards 1926; Jongmans u. Gothan 1935 and previous literature)*.

In 1933 Ting and Grabau *(1934, pp. 7–8)*, who were also impressed by the sharp contrast between these neighbouring floras, suggested another view as to the nature and position of the barrier between the Indian and Far Eastern botanical provinces. In a map of SW China *(l. c, fig. 2, p. 8)* they showed the western limit of the *Gigantopteris* flora in a NS line roughly along the meridian 103°·30′ E, bounded on the west by a NS belt of high basaltic table land of great thickness and lateral extent. "This highland", they wrote, "must have been an effective barrier between the *Gigantopteris* flora in China and the *Glossopteris* flora in India". As they took no account of a possible ocean barrier between India and China, about which Halle had already hinted in 1927, it appears that they believed the geographical relations of the two provinces to have been at the end of the Palaeozoic era the same as they are to-day. It is difficult to say for how long a mere basaltic plateau can have remained effective as a barrier between two closely neighbouring floral provinces, connected by land along a front extending all the way southwards as far as Sumatra. On the other hand, the meridional belt of mountains in the Assam-Burma-Malaya region, continuous at its northern end with the E. Himalayas in Assam, naturally suggests itself as a boundary between the two provinces and fully explains the floristic contrast as being due to the former ocean barrier which it now represents.

From what has been said above the importance of pushing investigations both from the east and west (that is from the Chinese as well as from the Indian sides of the barrier), so as to narrow down the intervening *terra dubia*, will be evident. Quite probably the *Gigantopteris* flora will be found to have extended a good deal

further west than Ting and Grabau believe. Just as in northern India members of the *Glossopteris* flora have been discovered at several places in the old coastal districts of Gondwanaland from Kashmir as far as Assam, so also explorations in Szechuan, Yunnan, Indo-China and even eastern Burma should help to establish the opposite coastline of the arcto-carboniferous continent, which probably lay to the west of the Shan plateau of Burma. It would also be interesting to know the eastern limit of our Indian *Glossopteris* flora in the region between N. E. Assam and the Irrawady delta. Palaeobotanically the large triangular tract west of the Arakan Yoma, between the Irrawady and the Brahmaputra rivers, is almost completely unknown. If ever fossil plants of late Palaeozoic age should be found in this area, they may be expected to belong to the *Glossopteris* flora.

(vii) *Possible means of intermigration.*—As stated above, at present there is not much evidence of an affinity between the *Glossopteris* and *Gigantopteris* floras. The authoritative opinions of Professor Halle *(1927, p. 289)* and of Professors Jongmans and Gothan *(1935, p. 185)* on this subject have already been cited above. They are all emphatic that the two floras are quite distinct, with not a single *species* in common. I have italicised the word *species* purposely: for at least there are some *genera* common to the two floras, and in one or two cases the species appears to be closely allied. These genera are *Sphenophyllum, Odontopteris (Dicroidium?), Protoblechnum* (also possibly a *Dicroidium?)* and *Rhipidopsis;* possibly also a *Schizoneura,* and a *Phyllotheca.* Halle, at least, agrees *(p. 290)* that a few of the species indicate Gondwana affinities. As stated earlier, some reports of an intermingling of the floras have also been made, although they still await confirmation. Taking these affinities for whatever they are worth (and it would be rash to exaggerate them) the question arises, how are they to be explained?

We know already that a similar question exists about the gondwanoid affinities of the Late Palaeozoic flora of Angaraland. Zalessky explained these affinities by assuming the presence of either a direct land connection with the southern continent or of an archipelago which may have served as stepping stones across the Tethys. In a brief note sent to *Nature,* which I hope will soon be published, I have quite recently drawn attention to the fact that Zalessky's hypothesis has been supported by the geological field work of D. N. Wadia *(1934, pp. 144–146)* in N. W. Kashmir. This work clearly supports the idea of a northward route of migration for land plants through this region, where the Gondwana Continent projected north as a triangular promontory. My object in mentioning these facts here is to suggest, tentatively, that perhaps the acute-angled Assam promontory of Gondwanaland may have marked the position of another route of migration across the Late Palaeozoic sea separating India from China.

II. *Mesozoic.*

(a) The Shan States flora more allied to the Far Eastern.—No Palaeozoic plants have yet been discovered in Burma, but I have for several years suspected that the Shan States, adjoining Yunnan, should be regarded as a part of the Far Eastern botanical province and not of Gondwanaland. The Mesozoic fossil flora of the Shan States still needs critical examination from the point of view of its geographical relations. My cursory survey of the collection in Calcutta, undertaken about ten years ago, did not reveal any species obviously referrable to the Indian Upper Gondwana flora, which is fairly well known. Though one of the conifers seemed to be allied to a species from Cutch *(Sahni 1928, p. 26)*, two species of *Cupressinocladus* from the Kalaw coalfield in the Southern Shan States *(see Sahni 1931, pl. IV, figs. 52–59, p. 116, footnote 3)* showed a closer resemblance with some Chinese forms than with any from Gondwanaland. On the whole, so far as it is known, the flora seems clearly more related to the Chinese Mesozoic flora than with that of the Upper Gondwanas. But here, as elsewhere, the sharp contrasts of the Palaeozoic have not persisted into the Mesozoic.

(b) Yunnan and Tonkin: a province distinct from Gondwanaland.—Some fossil plants from Yunnan collected by Dr. J. Coggin Brown of the Indian Geological Survey which, thanks to the courtesy of Professor Painvain of the École des Mines, Paris, I was able to compare in 1930 with Zeiller's type specimens from Tonkin *(1903)*, show unmistakable affinities with that flora, and none with the Indian Gondwana flora. Below is a provisional list of the species, based chiefly upon determinations by Professor Sir A. C. Seward.[1]

Loc. 1.—YUNNAN-HSIEN.

- ? *Podozamites distans* (Presl) Braun.
- ? *Podozamites lanceolatus* (L. & H.).
- *Incertae.*

Loc. 2.—MIAO-TSWAY.

- *Equisetites Sarrani* (Zeill.).
- *Dictyophyllum Remauryi* (Zeill.)
- *Taeniopteris Jourdyi* (Zeill.).
- *Dictyophyllum Nathorsti* (Zeill.)
- *Cycadites Saladini* (Zeiller.).
- *Pelourdea Zeilleri* sp. nov. (This is no doubt identical with Zeiller's supposed *Noeggerathiopsis Hislopi* from Tonkin).

[1] See *Rec. Geol. Surv. Ind.* XLII, p. 26 (Director's General Report for 1928), 1929.

Parallel-veined Impressions.

Scales.

Branched Rachis and Roots.

Stem with seed-like bodies.

It is true that Zeiller thought he had identified some typical Lower Gondwana plants in his Tonkin flora, particularly *Noeggerathiopsis*, two species of *Glossopteris*, and *Palaeovittaria Kurzi* Fst. The position of Tonkin being definitely on the other side of the suspected barrier it was important to check the supposed Gondwana elements in Zeiller's collection in Paris, especially those he had identified with members of the *Lower* Gondwana flora, which is undoubtedly older than that of Tonkin. I therefore made a special visit to Paris in March 1930. In the rather confused state of this important collection in the museum many of the types could not be traced, but I was able to confirm from numerous specimens (as indeed may be seen at once from Zeiller's figures) that at least the *"Noeggerathiopsis Hislopi"* had been wrongly identified. Others have similarly doubted the reported occurrence of Lower Gondwana plants and animals in the Tonkin beds *(Fromaget 1934 a, p. 135)*. Probably all palaeobotanists now agree that the Tonkin flora, formerly classed as Rhaetic and too readily accepted as a residual Gondwana flora, has its affinities in quite a different direction. At the same time, as Fromaget has pointed out, there are indications that towards the end of the Palaeozoic and in early Mesozoic times the sea barrier was sporadically interrupted.

Summary and Conclusions

This paper elaborates and confirms certain views previously published by the author *(Sahni 1926, 1931, 1931 a, 1935, 1935 a)*.

(1) We have not yet enough palaeobotanical data to prove the *drifting apart* of the different portions of Gondwanaland *(1926)*.

(2) But we at least seem compelled to agree that drift movements of large magnitude elsewhere have *brought into juxtaposition* continents once separated by wide oceans *(1935, 1935 a)*.

(3) It therefore seems impossible to get away altogether from the idea of continental drift. But the details of Wegener's theory must stand on their individual merits.

(4) Views previously expressed by the author concerning the sharp angle in the strike of mountain ranges in N.E. Assam, and concerning the southern extension of the Himalayan axis as far as the Malay archipelago *(1935, 1935 a)* are confirmed.

(5) If the Himalayas are still rising, as some geologists believe *(Wadia 1936, p. 64; de Terra 1935, p. 73)* then we may conclude that the northern and southern continental blocks are still pressing

towards each other; and if the sharp knee-like bends in the axis of the Himalayas have been formed, as suggested, by rotation round the two pivots of Kashmir and Assam, then accurate longitude records carried over a number of years may show that the distance between points in Baluchistan and the Shan plateau is still becoming shorter.

(6) The affinities of the Mesozoic flora of Yunnan (as far as it is known) are distinctly with that of Tonkin. Both these floras are distinct from any known Gondwana floras. This fact is in consonance with their geographical position beyond the tectonic boundary between India and the Far East.

(7) For similar reasons the Shan States of Burma should also be regarded as outside the province of Gondwanaland *(1931)*.

(8) Although on the whole the *Glossopteris* and *Gigantopteris* floras were very distinct, it appears that during Permo-Triassic times some means of communication between the two continents existed. By analogy with the conditions in Kashmir which according to Wadia had a more or less interrupted connection with Angaraland, it is suggested tentatively that the Assam promontory of Gondwanaland may similarly mark the position of a former land connection with the *Gigantopteris* province.

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TERRA, see de Terra.

TOIT, see du Toit.

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REVIEW

NEUMANN, MARGARETE. Die Entwicklung des Pollens, der Samenanlage und des Embryosackes von *Pereskia amapola* var. *argentina*. Osterreich. Bot. Zeitschr. *84* : 1-30. 1935.

F. VAUPEL (1925) writes as follows in the latest edition of ENGLER-PRANTL'S *Pflanzenfamilien*: "Es gibt wohl kaum eine Familie im ganzen Gewächsreiche, deren systematische Gliederung dem Geschmack des Einzelnen soviel Spielraum lässt, wie gerade die Cactaceae. Der Grund dazu liegt in der Vielgestaltigkeit des Körpers und seiner Organe, den vielfachen Uebergängen und der auch heute noch nicht ganz behobenen Unzulänglichkeit des Materiales vieler Arten". WETTSTEIN (1935) places it in the Centrospermales between the Aizoaceae and Portulacaceae. WARMING (1933) is not so certain, but thinks WETTSTEIN'S view to be the best. In ENGLER-PRANTL, on the other hand, it is given a totally different place, viz., in a separate order Opuntiales near the Passifloraceae, and Hutchinson (1926) holds a similar opinion.

The paper under review is an excellent example of the service of embryology in the solution of phylogenetic problems. The earlier work of DR. MAURITZON (1934) on species of *Rhipsalis* and MISS NEUMANN'S present work on *Pereskia* fully confirm the opinions of the late Prof. R. WETTSTEIN and his son Prof. F. v. WETTSTEIN, who is responsible for the latest edition of the "*Handbuch der systematischen Botanik*". The features characteristic of the embryology of the Centrospermales and also found in *Pereskia* may be enumerated briefly as follows:—a secretory tapetum that is parietal in origin; simultaneous division of the microspore-mother-cells; 3-nucleate pollen at the time of shedding; campylotropous ovule with a strongly curved and massive nucellus; two integuments of which the inner forms the micropyle and whose swollen lips protrude out to approach the funiculus; hypodermal archesporial cell which cuts off a wall-cell; nucellar cap formed by periclinal divisions of the epidermis; 3-4 celled tetrad of megaspores; and embryo-sac of the normal type.

Several other special characters, for which a reference should be made to the full paper, point to the conclusion that the Cactaceae form a sort of bridge between the Aizoaceae and the Portulacaceae. A point that has probably been overlooked by several workers but which is nevertheless of considerable importance is the characteristic "Hohlraum" or "Luftspalte" between the two integuments and sometimes also between the inner integument and the nucellus in the chalazal region of the ovule. NETOLITZKY (1926) thinks it to be quite characteristic

of the Portulacaceae and recently H. R. BHARGAVA, has seen it in some members of the Amarantaceae.

On the other hand, a comparison of these results with the work already done on the Passifloraceae and Loasaceae (Engler puts the Cactaceae near these families) shows no striking resemblances. As remarked by MAURITZON (Botaniska Notiser, 1935, p. 133):—"In der Embryologie der beiden Familien (Cactaceae und Passifloraceae) gibt es also nicht einen einzigen typischen gemeinsamen Zug, wenn man von so allgemeinen und gewöhnlich vorkommenden Erscheinungen wie nukleares Endosperm und ähnlichem absieht . . . Eine Verwandtschaft zwischen Cactaceae und Loasaceae ist vom embryologischen Standpunkte ganz undenkbar und braucht nicht einmal erortert zu werden."

P. MAHESHWARI.

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STUDIES ON CAPPARIDACEAE
II. THE EMBRYOLOGY OF *GYNANDROPSIS PENTAPHYLLA*

BY

V. S. RAO, B.A., M.SC.

Benares Hindu University

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Introduction

This is the second paper of the series upon the life history of Capparidaceae, the first one (4) upon *Maerua arenaria* having already been published. In the present paper will be described the embryology of *Gynandropsis pentaphylla*, instituting comparisons with *Maerua* as occasion arises. In the sequel will be made a few remarks upon *Cleome viscosa* also.

As the literature concerning the whole family has been given in my earlier paper, I here confine myself to mentioning only those papers which refer to *Gynandropsis* and *Cleome* and to such other work as has recently appeared in the press.

A few stages here and there in the megasporogenesis and embryo development of *Gynandropsis pentaphylla* have been mentioned by Mauritzon (3) but the account is very fragmentary and incomplete, lacking both in observations and in sequence. The microsporogenesis, besides, has so far not been studied at all. As for *Cleome viscosa* the only clear account that is so far

published is a note by Tiwary (5) dealing with the megasporogenesis and embryo development. The chromosome number of this plant has been reported upon by Janaki Ammal (1).

The present paper deals only with the facts as observed, leaving the discussion upon the family to a later paper.

Material and Methods

The material was fixed in a number of fluids—Allen's modification of Bouin's fluid, Carnoy's fluid, weak chromoacetic fixative, and Bouin's fluid. Of these, the first two gave the best results. The fixation was facilitated by the use of an exhaust pump, and was done on bright sunny days between 10 a.m. and 2 p.m. Although *Gynandropsis* gave excellent preparations of all stages, both in mega- and micro-sporogenesis, for *Cleome*, perhaps owing to the excessively hairy nature of the buds, the division stages in the pollen-mother-cell could not be obtained, and for this reason, the microsporogenesis of *Cleome viscosa* has been left over for a future paper.

The paraffin method was employed, and sections were cut ranging from 6 microns to 12 microns in thickness, according to the age of the flower buds. The following stains were used—(1) Haidenhain's iron-alum haematoxylin, (2) the same using safranin as a counter stain, (3) safranin and gentian violet, and (4) safranin and light green. The first one gave the best results. The long over-night schedule of using this stain proved, after trials, to be better than the shorter schedule.

Observations

Development of the Ovule

The nucellus arises as a papillate outgrowth, almost cylindrical in shape in the beginning, (Fig. 1) but becomes club-shaped later on. It is at this stage that the primary archesporial cell is differentiated in the hypodermal layer. The curvature in the ovule from the straight position begins soon after only a few parietal cells have been formed (Fig. 2) and simultaneously with this, the integuments also begin to develop. The origin of the integuments is indicated by a prominent bulging of the ovule, especially on the side away from that towards which the ovule is curving. The two integuments arise simultaneously and by the time they have attained a recognisable size, the ovule curves through about 70° to 80°. By the time the megaspore-mother-cell is organised, the ovule makes usually an angle of 90° with the funiculus (Fig. 3) and the integuments are about half way through their growth. The curvature continues, and when the ovule has become anatropous (Fig. 4) it often contains a young 8-nucleate embryo-sac. This indicates that the rate of curvature is much less at this stage than in the earlier stages. The integuments are now found enveloping the nucellus. The mature

campylotropous form (Fig. 5) is attained by a localised growth on the chalazal side of the nucellus. By this time, the organization of the mature embryo-sac is over. The nucellus is almost pointed on the micropylar side. The funiculus is united along its entire length with the nucellus, as in an anatropous ovule. This observation of mine agrees with that of Mauritzon (3). He also mentions that the ovule begins to curve simultaneously with the primordium of the integument in the species of Capparidaceae observed by him. The ovule is far more bulky on the chalazal side than on the micropylar. No difference can be found in the massiveness of the two integuments. Although in the earlier stages the integuments do not surround the nucellus tightly, this takes place as the ovule advances in age.

Megasporogenesis

Usually a single hypodermal cell (Fig. 6) of the nucellus becomes the primary archesporial cell; in a few cases, two are also found to become developed. Figure 1 shows one such condition in which there are two sporogenous cells lying side by side, each having cut off a parietal cell. The primary archesporial cell divides by a periclinal wall into the primary parietal cell and the primary sporogenous cell. A small amount of parietal tissue (Fig. 7) is developed by further divisions in the primary parietal cell. The first division in this is sometimes periclinal and sometimes anticlinal, but more often, the former. The parietal tissue is not very extensive.

The primary sporogenous cell, sunk about 5 or 6 cells deep in the nucellus, rapidly increases in size and becomes the megaspore-mother-cell.

By two successive divisions, a T-shaped tetrad (Fig. 8) is formed. In two or three ovules, only a row of three megaspores (Fig. 9) was found. It cannot definitely be stated which division was suppressed in these cases. In *Maerua* it is always a linear tetrad that is formed. The megaspore at the chalazal end functions and develops into the embryo-sac, while the other megaspores degenerate. It enlarges in size, the cytoplasm becomes less dense and vacuolate, and one vacuole on either side of the nucleus becomes prominent. The nucleus lies almost in the centre of the cell. The further development goes on in the normal way, and an 8-nucleate embryo-sac (Fig. 11) is formed, four of the nuclei lying at the micropylar end, and four at the chalazal end. All the nuclei at this stage are of equal size, and a big vacuole lies in the middle of the embryo-sac which is now twice as long as it is broad. The width of the sac at the micropylar end is slightly greater than at the chalazal end. The central vacuole is almost a constant and general feature. In the formation of the 4-nucleate embryo-sac (Fig. 10), the division of the nucleus at the chalazal end usually takes place in a plane parallel to the long axis of the sac, and that of the micropylar

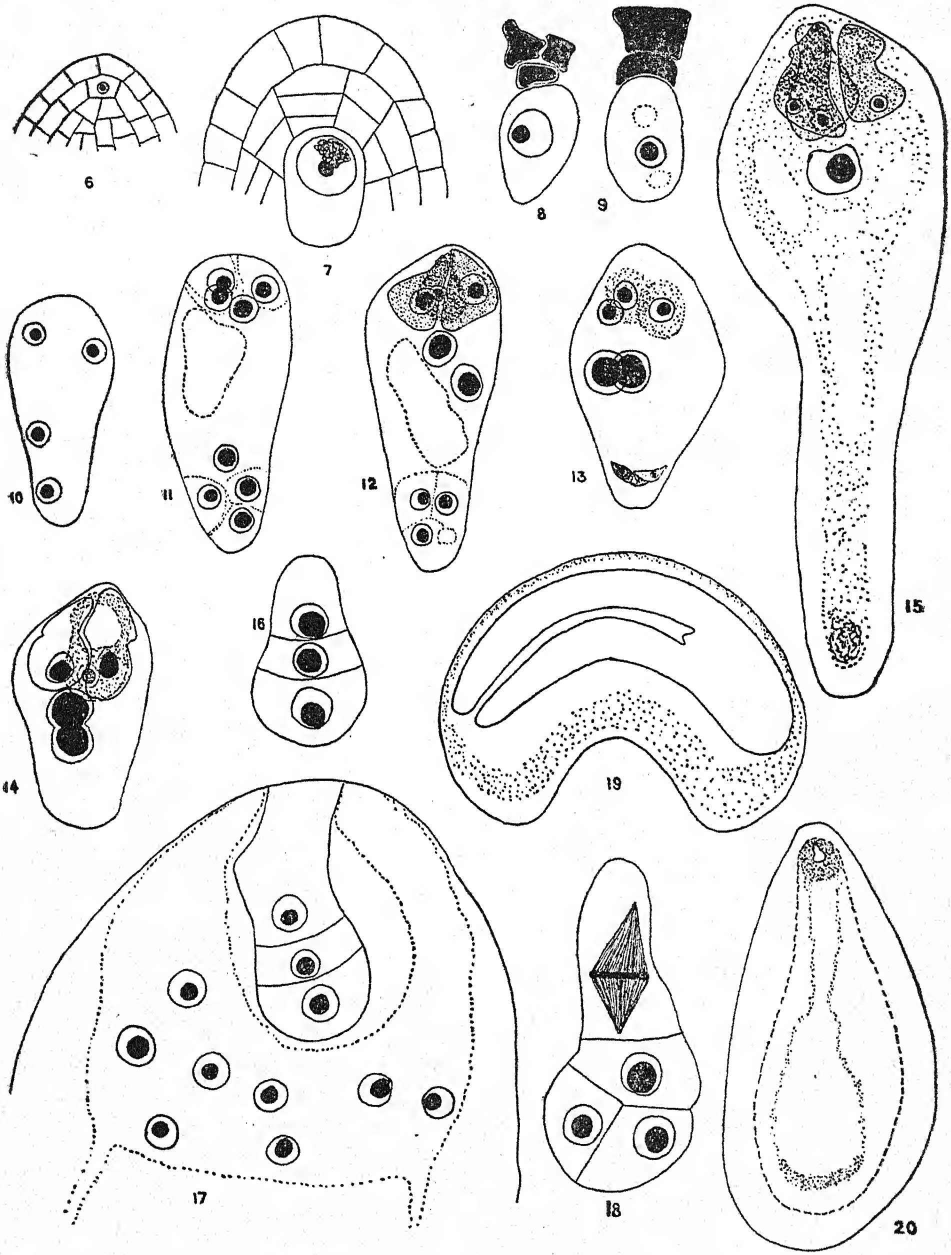
nucleus in an oblique, if not indeed a horizontal plane—*i.e.*, the plane at right angles to the former. This condition has also been observed in *Boerhaavia diffusa* by Maheshwari (2), and is no doubt due to the differences in the width of the embryo-sac at the chalazal and at the micropylar ends.

After the formation of the eight nuclei in the embryo-sac, three nuclei at the micropylar end and three at the chalazal end accumulate cytoplasm round about themselves, the former being organised into the usual egg apparatus, and the latter into the antipodals (Fig. 12).

Each of the two polar nuclei attains nearly double the size of any other. Figure 13 shows a condition in which the antipodals are organised before the organisation of the egg apparatus. The chalazal polar nucleus migrates rather early towards the micropylar side and lies by the side of the polar nucleus on that side. The two lie at this stage slightly away from the egg apparatus. The young 8-nucleate sac is about twice the size of the 4-nucleate sac. In *Maerua* the embryo-sac, from the 4-nucleate stage onwards is curved, and this is due to the length of the sac there, and its consequent adaptation to the curvature of the ovule. In *Maerua* the young 8-nucleate sac is nearly 5 or 6 times as long as it is broad, but here in *Gynandropsis*, it is relatively short.

The young synergids (Fig. 12) are somewhat wedge-shaped, and filled with dense cytoplasm. As growth proceeds, each

Figs. 1—5. *Gynandropsis pentaphylla.* Fig. 1. Origin of the nucellus. Nucellus contains two sporogenous cells side by side. × 600. Fig. 2. Origin of the integuments. × 450. Fig. 3. Curvature of the ovule. × 450. Fig. 4. Anatropous condition of the ovule. × 100. Fig. 5. Mature campylotropous form of ovule. × 62.



Figs. 6—20. *Gynandropsis pentaphylla.* Fig. 6. Hypodermal archesporial cell. × 600. Fig. 7. Megaspore mother cell. × 1000. Fig. 8. T-shaped tetrad. × 1000. Fig. 9. Row of three megaspores. × 1000. Fig. 10. 4-nucleate embryo-sac. × 1000. Fig. 11. 8-nucleate embryo-sac. × 1000. Fig. 12. Young embryo-sac. × 1000. Fig. 13. Embryo-sac where antipodals are organised before the egg apparatus. × 1000. Fig. 14. Fusion of the polar nuclei. × 1000. Fig. 15. Mature embryo-sac. × 1000. Fig. 16. 3-celled embryo. × 1000. Fig. 17. 3-celled embryo in nuclear endosperm. × 1000. Fig. 18. Later stage in embryo development. × 1000. Fig. 19. Mature embryo. × 62. Fig 20. Ovule showing the distribution of endosperm nuclei. × 123.

develops a beak-like protuberance on one side (Fig. 14) but the synergids themselves do not enlarge very much in size. Some mature synergids have been found in which the beak is only slightly developed or not at all. As other synergids either older in age or of the same age show the beaks, it cannot be said that the beak disappears in older stages. It is more probable that the beak is not developed in some. Mauritzon also, in his general account on the Capparidaceae he worked, mentions that such a protuberance is developed in the plants worked upon by him in old stages. He says that the vacuole lies beneath the nucleus but my observations do not coincide with his on this point. The nucleus lies at the very base of the synergid, and there is no space at all there for any vacuole to exist. In *Maerua* we meet with long synergids without beaks, but with a filiform apparatus.

The egg lies in the same plane as the synergids. This also, in the young condition, has a slightly wedge-shaped appearance (Fig. 12) but becomes pear-shaped later on. The nucleus lies at the base of the egg, and there is a prominent vacuole on the micropylar side of the nucleus (Fig. 14). In *Maerua*, the common condition for the egg is to lie at the base of the synergids.

The fusion of the two polar nuclei occurs in close proximity to the egg cell (Figs. 14, 15,) at about the time of fertilization By the time the secondary nucleus is formed (Fig. 15) the embryo-sac begins to increase in length.

The antipodals, (Figs. 12, 13) which are small, disorganise at an early stage before the fusion of the two polar nuclei. Stages showing the degeneration of the synergids are not obtained, but the degeneration is definitely after the fertilization of the egg.

The antipodals of this plant form a strong contrast to those of *Maerua* where they attain a very large size, and occupy the whole of the lower half of the embryo-sac.

Development of the embryo and endosperm

The first two divisions in the fertilised egg are always transverse, and result in a row of three cells (Fig. 16). The basal cell is sometimes a little elongated (Fig. 17). By this time the secondary nucleus divides and forms a number of endosperm nuclei which group themselves round about the proembryo of three cells (Fig. 17). The embryo-sac has grown much in all directions, and is bent to the shape of the ovule.

The next division in the apical cell is longitudinal (Fig. 18). The basal cell also may again divide transversely (Fig. 18). Details of further divisions are not available. The seed, just previous to its being shed, contains a fully developed, completely differentiated embryo with the cotyledons and the primordium of the plumule (Fig. 19).

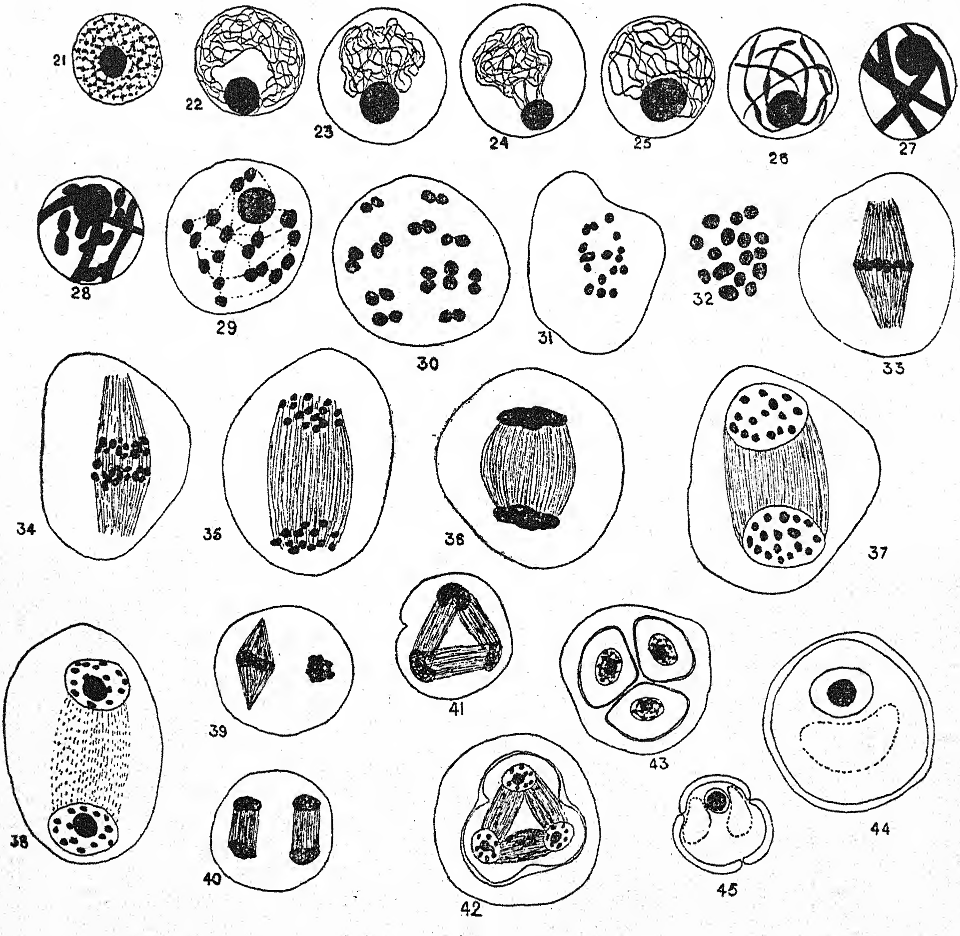
The endosperm is of the nuclear type, and in the beginning consists of a mass of nuclei round about the embryo embedded in dense cytoplasm, and a much smaller number of nuclei at the chalazal extremity of the sac (Fig. 20). Between these two groups, we find only extremely few endosperm nuclei present within the sac. The whole of the endosperm is consumed by the growing embryo and even a great portion of the nucellus also is eaten away by it, so that ultimately the mature embryo is surrounded by only a few layers of nucellar cells.

Reduction Division in the pollen-mother-cell and the development of the pollen grains

The pollen-mother-cell has got a thin cellulose wall enclosing dense cytoplasm and a large nucleus. The nucleus contains a single nucleolus which is usually excentric in position The resting nucleus contains a faintly staining reticulum (Fig. 21) and the knots are not very prominent. As the pollen-mother-cell and its nucleus enlarge, the knotty nature becomes only slightly more apparent. The nucleolus stains a perfect black with iron-alum haematoxylin. The nuclear reticulum gradually attains a more prominent appearance, and is resolved into leptotene threads (Fig. 22). Simultaneously with this, the knotty appearance becomes lost, probably owing to a uniform distribution of the chromatic material. At this stage usually the leptotene threads occupy a peripheral position in the nucleus, leaving a clear space round about the nucleolus (Fig. 22). The leptotene threads appear to form a continuous spireme instead of separate threads at this stage. This gradually converges towards the nucleolus (Fig. 23) increasing in thickness and thereby in prominence during the process. The convergence of the leptotene threads does not usually take place along the nuclear wall, but directly through the nuclear cavity. During this contraction the threads do not present any appearance of regular loops. The greater part of the knot is often made even when it is some distance away from the nucleolus (Fig. 24), and this is ultimately dragged close to the latter, to form the synizetic knot (Fig. 23). The nucleolus, during these processes, does not show any change at all, either in size or colour reactions. During synapsis, the component threads could not be recognised owing to the closeness of pairing, to the very small size of the nuclei, and to the slenderness of the chromatic threads.

When the synizetic knot loosens, the chromatic thread is thrown out into irregular loops extending over the greater part of the nuclear cavity, thus entering upon the open spireme stage (Fig. 25). By this time, the slenderness of the chromatic thread is lost, and it gets a more prominent appearance. In spite of extensive observations no second contraction could be found here, and it can, with certainty be stated that it is absent. It is from now that the chromatic double thread increases rapidly in

thickness, and contracts in a marked manner (Figs. 26 and 27). The thread breaks up into the various pairs of chromosomes



Figs. 21—45. *Gynandropsis pentaphylla.* Fig. 21. Resting nucleus of pollen mother cell. × 2500. Fig. 22. Leptotene stage. × 2500. Fig. 23. Synizesis. × 2500. Fig. 24. Organisation of the synizetic knot. × 2500. Fig. 25. Open spireme stage. × 2500. Fig. 26. Contraction of the double thread. × 2500. Fig. 27. Fully contracted thread. × 2500. Fig. 28. Breaking up of the thread into individual chromosomes. × 2500. Figs. 29 & 30. Pre-diakinesis and diakinesis. × 3000. Figs. 31 & 32. Chromosomes at the equatorial region. × 2000 and × 3000, respectively. Fig. 33. Metaphase. × 3000. Fig. 34. Anaphase. × 3000. Fig. 35. Late anaphase. × 3000. Figs. 36 & 37. Telophase. × 3000. Fig. 38. Daughter nuclei, × 3000. Fig. 39. Homoeotypic metaphase. × 2000. Fig. 40. Parallel spindles. × 2000. Fig. 41. Early telophase. × 2000. Figs. 42 & 43. Formation of the pollen grains. × 2000. Figs. 44 & 45. Young and mature pollen grains. × 3000 and × 2000, respectively.

(leading to the diakinesis stage) which appear as darkly staining globular bodies (Figs. 28 and 29). The bivalent chromosomes, throughout their appearance present a globular shape, and lie scattered within the nuclear cavity (Fig. 30). In the primary stages, fine fibre-like connections are found to connect the gemini to each other, but these too later disappear. The two globular chromosomes composing each of the gemini lie separated, side by side, and are not united in any region, as usually happens (Fig. 30). It is at this stage that the nucleolus is disorganised.

The bivalent chromosomes arrange themselves at the equatorial region and the nuclear membrane is dissolved (Figs. 31, 32). Counts of chromosomes in cells at this stage gave the haploid number sixteen. The chromosomes are of unequal size. An achromatic spindle with blunt ends is organised, some of the fibres of which get attached to the chromosomes. (metaphase) (Fig. 33). The anaphase shows no peculiarities. Even at the metaphase the individual chromosomes are distinguishable. The chromosomes are drawn unequally to the poles (Figs. 34, 35) and at the beginning of the telophase the chromosomes are densely crowded at the poles (Fig. 36). The achromatic spindle is sometimes slightly barrel-shaped, and sometimes has straight edges. As the construction of the daughter nuclei proceeds, the denseness is lost and the individual chromosomes become widely separate from each other (Fig. 37). A nuclear membrane is organised round about them, and a nucleolus makes its appearance (Fig. 38). Fine threads are seen to connect the chromosomes in the telophasic nuclei.

The details leading to the second division are not available. The interphase is of a short duration. The homoeotypic division of the two nuclei is simultaneous. The spindles, unlike those of the heterotypic division, are pointed at the poles (Fig. 39). The homoeotypic figures may either be parallel to each other or at right angles (Figs. 39, 40), but more frequently it is the latter and results in a tetrahedral arrangement of the microspore. The formation and development of the microspores are as usual without any deviations. The microspores are organised by furrowing (Fig. 42). The mature pollen grain has a somewhat thick exine and a thin intine, and contains a single nucleolus (Figs. 44, 45). It has usually three germ pores and the cytoplasm has two vacuoles, one on either side of the nucleus.

The flowers are definitely protandrous, fully developed pollen grains being present in the anthers even when the primary archesporial cell is not differentiated in the ovules.

Cleome viscosa

I confirm all the points mentioned by Tiwary (5) in his note upon the megasporogenesis of this plant. He mentions an

embryo-sac in which the antipodals show an extension towards the chalazal side, but in spite of extensive observations, I could not observe a similar condition in *Gynandropsis*, all the embroy-sacs obtained by me conforming to the normal type described by him. In all essentials, this plant agrees with the type described, namely *Gynandropsis pentaphylla*. The endosperm is greater in quantity, and the flowers here also, are markedly protandrous.

Moreover in the development of the ovule in *Cleome viscosa* I understand that usually the outer integument grows more than the inner and thereby the micropyle is broken up into two parts—that formed by the inner integument, and that formed by the outer.

Summary

(1) The primary archesporial cell is hypodermal in position.

(2) A T-shaped tetrad commonly, and a row of three megaspores occasionally, is developed.

(3) The development of the embryo-sac is normal.

(4) Endosperm is nuclear.

(5) The haploid number of chromosomes is sixteen.

(6) The megasporogenesis of *Cleome viscosa* is similar to that of *Gynandropsis pentaphylla*.

Acknowledgments

I wish to express my gratitude to Prof. N. K. Tiwary for his kind and able guidance. I also thank Dr. Y. Bharadwaja for permitting me to work in the laboratory, and giving me all the facilities.

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STRUCTURE OF THE NUCLEUS IN THE GENUS *PYTHIUM*

BY

R. K. SAKSENA, DOCTEUR ÈS SCIENCES (PARIS)

Department of Botany, University of Allahabad, Allahabad

Communicated by Professor J. H. Mitter, Ph.D. (London) Allahabad

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The typical resting nucleus in *Pythium deliense* Meurs, *P. de Baryanum*, *P. mamillatum* Meurs and *P. indigoferae* Butler is more or less spherical in shape with a distinct nuclear membrane (Saksena, p. 244). The main portion of the nucleus consists of a central body, which occupies nearly half the space within the nuclear cavity and is very prominent by its size and staining qualities, appearing jet black when stained with iron-alum hæmatoxylin. Surrounding this is the karyolymph, which in all good preparations is seen traversed by loose delicate linin threads by which the central body is suspended within the nuclear cavity. Occasionally the granules of chromatin are seen as small mounds chiefly on the inner surface of the nuclear membrane (Fig. 1). The views of various workers about the nature of the central body are conflicting.

In 1901, Trow published his observations on *Pythium ultimum*. He describes the central body as a chromatic mass (1. c. p. 298). " When karyokinesis begins the chromatic mass gradually breaks up, the chromatin passes out on to the linin threads, and a distinct nucleolus remains behind (1. c. p. 299)". In short the central body, according to him, is really equivalent to a nucleolus and chromatin. In 1904, he wrote, " I must object to the view that the central body has been proved to be a nucleolus. This is not so much a question of the relative value of preparations, concerning which every botanist may be allowed to have his opinion, but rather of the interpretation of observations. If this conspicuous structure is a nucleolus, it is a giant of its kind, and such nucleoli in the higher plants would excite considerable interest. I have looked in vain for figures of such. My present conception of this problematic body, which I provisionally regarded as a ' Chromosome ' in 1895, may be best realized if we

imagine the nucleolar matter in the nucleus of a lily to increase in amount to such an extent as to half fill the nuclear cavity, and in doing so, to enclose, not displace a large portion of the pre-existing linin network and the associated chromatin. This view, first promulgated in 1899, I am not yet prepared to discard" (Trow, 1904, p. 552).

Miyake, who worked on *P. de Baryanum*, published his observations in the same year (1901). He states that the nuclei contain the granules of chromatin and no nucleoli seem to be present (l. c. p. 656).

Edson (1915) investigated the cytology of *Rheosporangium aphanidermatum*, now known as *Pythium aphanidermatum*. According to him each of the nuclei within the prosporangia "contains typically a single nucleolus located at one side".

Patterson, in 1927, published an account of the oögenesis of *P. torulosum* and there he states that "the resting nucleus is similar to those of the Saprolegniaceae, consisting of a central chromatin mass, from which radiate a few linin strands to the nuclear membrane (l. c. p. 125)".

Recently Dangeard (1931) described the structure of the nucleus in *P. muscae*. He calls the central body a nucleolus (l. c. p. 452).

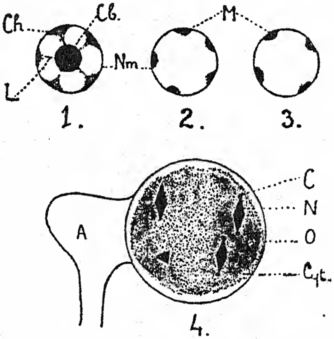
All these observers agree with the writer that there is a conspicuous central body within the nucleus in the various species of *Pythium* investigated by them. Only Miyake did not find this structure in *P. de Baryanum* but recently (Saksena, p. 245) it has been shown that there is a big central body in this species also. In *P. aphanidermatum* Edson did observe this body but found it located at one side of the nucleus.

The real controversy is about the nature of the central body within the nucleus. Is it a nucleolus (Edson, Dangeard and Saksena) or a nucleolus and chromatin (Trow) or only a mass of chromatin (Miyake and Patterson)?

The Feulgen Reaction

The nearly specific test so far known for the chromatic nucleo-protein ('chromatin') of nuclei is the Feulgen reaction (Sharp, p. 52; for technique see Langeron p. 1040). When preparations are treated with decolourized basic fuchsin, a purplish red colour appears within the nuclei in places where chromatin was present, indicating the formation of thymo-nucleic acid formed as a result of partial hydrolysis of the chromatin by hydrochloric acid used in this reaction, while the parts with no chromatin remain unstained. Heitz, Wermel, Yamaha, Shinke and Shingenga and others (for literature see

Sharp, p. 120) have reported that the Feulgen reaction gives negative tests for the nucleolus. Several workers (Eichhorn and Franquet, Allain, Hatch and others) have found this reaction giving positive tests for chromatin in plant cells.



Figs. 1—4. Fig. 1. A resting nucleus of *Pythium de Baryanum* stained with iron-alum hæmatoxylin. (X 3,600). Fig. 2. A resting nucleus of *Pythium deliense* treated for the Feulgen reaction. (X 3,600). Fig. 3. A resting nucleus of *Pythium de Baryanum* treated for the Feulgen reaction. (X 3,600). Fig. 4. Oogonium and antheridium (in section) of *Pythium deliense*. (X 1,350). Fixed in Flemming's strong solution and stained with iron-alum hæmatoxylin (chondriosomes are not sketched). A = antheridium, C = centrosome, Cb = central body (nucleolus), Ch = chromatin, Cyt = cytoplasm, L = linin thread, M = small mounds (stained purplish red in preparations), N = nucleus (in metaphase), Nm = nuclear membrane, O = oogonium.

The centre of each nucleus in the mycelium of *P. deliense P. de Baryanum, P. mamillatum and P. indigoferae* treated for the Feulgen reaction by the writer remains unstained, while small purplish red mounds are seen on the inner surface of the nuclear membrane (Figs. 2 and 3). *The result of this reaction clearly indicates that the central body is not made of chromatin* and that it is a nucleolus. The view of Trow that a nucleolus of a large size is not found in higher plants can no longer stand, since Eichhorn (1933, 1934) and others have shown that in Angiosperms a central voluminous nucleolus is present in the nucleus containing small chromosomes.

Centrosomes

The writer (Saksena, 1936, p. 282) has stated that centrosomes were not seen in the nucleus of *P. deliense* but further careful investigation of the nuclear division within the oogonia of this species has revealed the presence of two deeply stained spots, the centrosomes—one on either pole of the spindle (Fig. 4).

To Professor A. Guilliermond, Membre de l' Institute, of the University of Paris, I wish to express my grateful thanks for confirming my observations.

Summary

1. The central body seen in the nuclei of *Pythium deliense*, *P. de Baryanum*, *P. mamillatum* and *P. indigoferae*, gives a negative test with the Feulgen reaction and, therefore, is not a mass of chromatin. It is a nucleolus.

2. When nuclei divide within the oogonia of *P. deliense* centrosomes appear—one on either pole of the spindle.

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A NEW FORM OF *BOTRYDIUM* FROM LUCKNOW

BY

A. R. Rao, M.Sc.

Demonstrator in Botany, University of Lucknow

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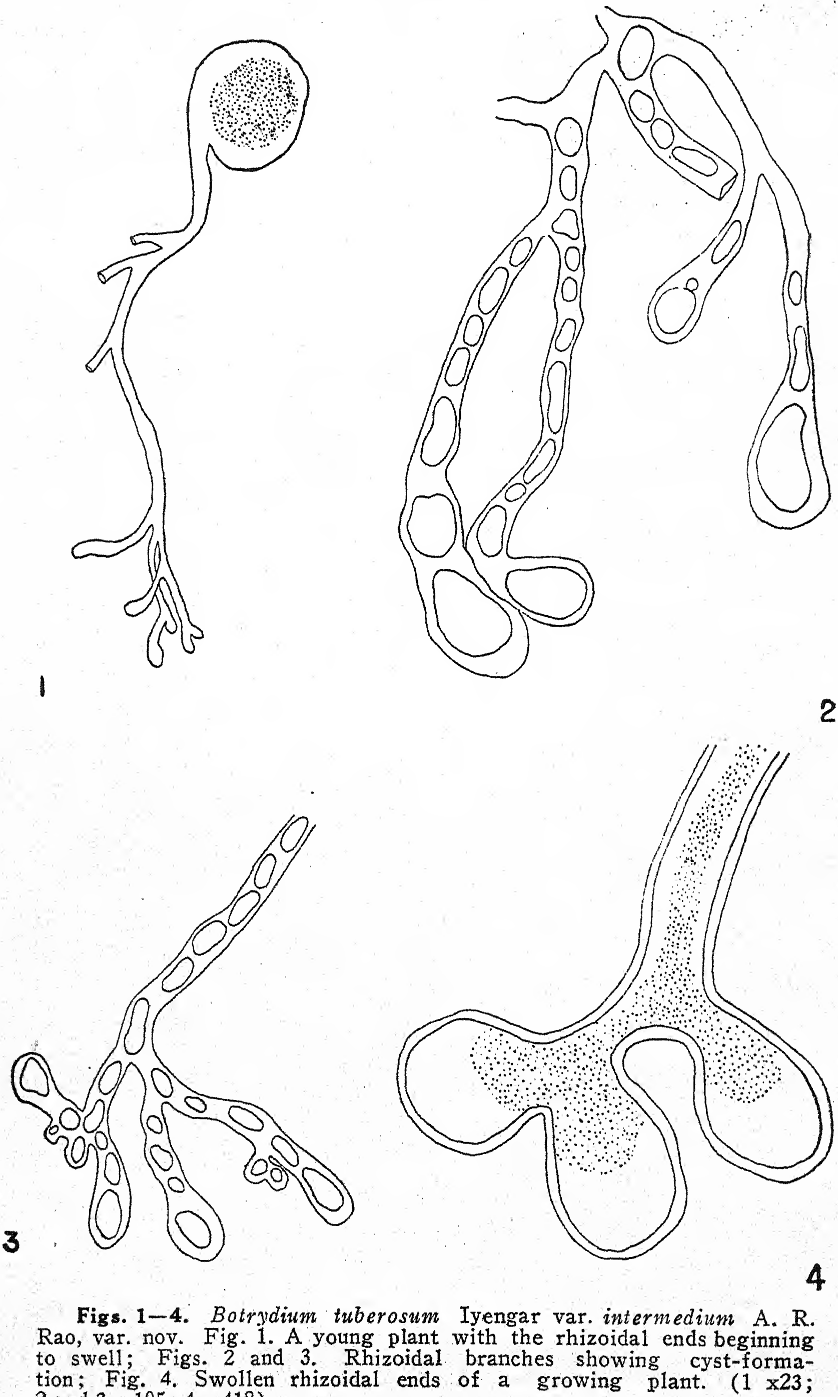
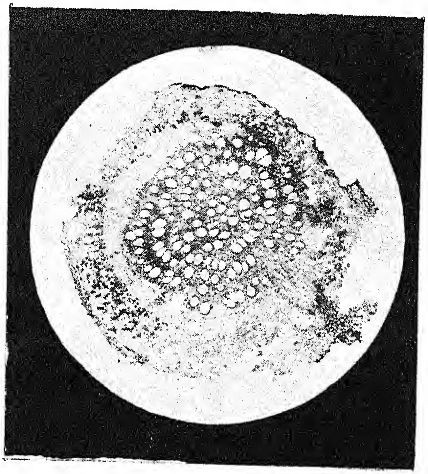
The alga forming the subject of this note was growing gregariously and formed green patches on wet mud on the banks of the river Gomati at Lucknow in January 1933. The plants resembled *Botrydium granulatum* (L.) Grev., but were somewhat smaller. The overground vesicle was spherical and unbranched, and when fully developed, was 0·5 to 0·75 mm. broad; it contained a large number of disc-shaped chloroplasts in each of which a pyrenoid-like body was discernible in the young plant. The rhizoidal portion was fairly well branched, the branching being more or less dichotomous.

Numerous plants producing cysts (hypnospores) were present. The cysts were formed by the migration of the protoplasm from the vesicle into the subterranean rhizoids, but, in the details of cyst-formation, the form under discussion combined the methods typical of the two species, *B. granulatum* (3) and *B. tuberosum* Iyengar (1). In the normal plant, long before the migration of the protoplast is indicated, the ends of the rhizoids swell (Figs. 1, 4) and become more or less rounded as in *B. tuberosum* (1,2). But, when the protoplast passes into the rhizoids, it fills not only their swollen ends forming a large cyst within each as in *B. tuberosum* but the remaining parts of the rhizoid also and forms a row of cysts as in *B. granulatum* (Figs. 2, 3). The branches of the rhizoid immediately above the terminal swellings are very much broader than in *B. tuberosum*. In the large size of the terminal cysts and in the development of serial cysts, this form differs both from *B. tuberosum* and *B. granulatum*. The terminal cysts of *B. tuberosum* are globose, ovate, elliptic or quadrate. The serial cysts are globose or irregularly elliptic and only very occasionally quadrate, and they are not placed close together as in *B. granulatum* (Figs. 2, 3).

The form above described thus combines certain characters of both *B. granulatum* and *B. tuberosum* and forms an interesting link between the two. It would therefore be possible



Figs. 1—4. *Botrydium tuberosum* Iyengar var. *intermedium* A. R. Rao, var. nov. Fig. 1. A young plant with the rhizoidal ends beginning to swell; Figs. 2 and 3. Rhizoidal branches showing cyst-formation; Fig. 4. Swollen rhizoidal ends of a growing plant. (1 x23; 2 and 3 x105; 4 x418).



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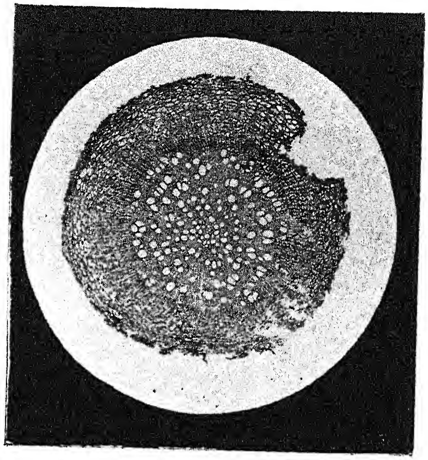

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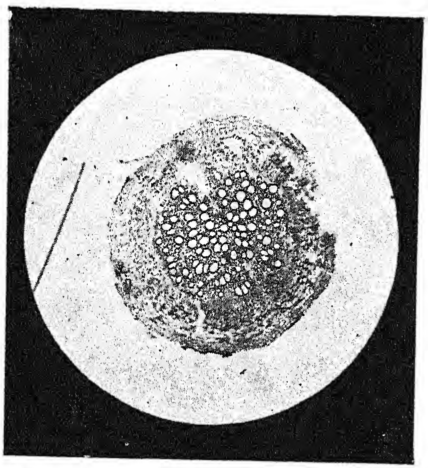

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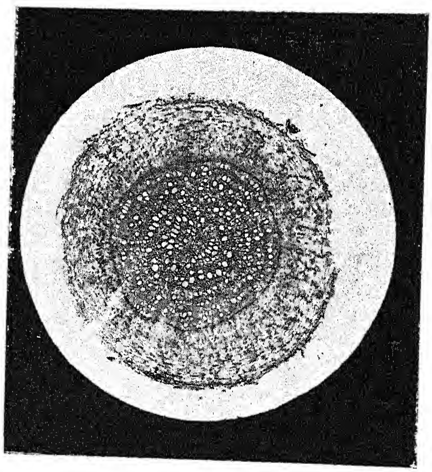

D

P. S. GUPTA—*ECOLOGICAL ANATOMY.*

to unite all three forms into the single species *B. granulatum* by emending the original description of this species. But since *B. granulatum* and *B. tuberosum* are such well marked species, it would seem better to regard the present form as a variety of *B. tuberosum*,* and to describe it as var. *intermedium*. It suggests that *B. tuberosum* may have been derived from *B. granulatum* by passing through a stage like that of the var. *intermedium*, the ends of the branches of the rhizoids first becoming swollen and later on cyst-formation in the remaining parts of the rhizoid becoming gradually eliminated.

Description

Botrydium tuberosum Iyengar var. *intermedium* A. R. Rao, var. nov. (*B. intermedium* Iyengar, 4) (Figs. 1-4).

Overground vesicle globose to ovoid, thin walled, with numerous disc-shaped parietal chloroplasts, tapering below into a well branched rhizoid; cysts globose or elliptic or ovate, formed serially as in *B. granulatum*, but with a comparatively large cyst in the swollen ends of the rhizoid-branches as in *B. tuberosum*.

Hab. On moist clayey soil on the banks of the river Gomati, Lucknow.

My grateful thanks are due to Prof. M. O. P. Iyengar and Prof. F. E. Fritsch for advice in preparing this paper. I am also indebted to Dr. M. A. Sampathkumaran for permission to work in his laboratory at the Central College, Bangalore.

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* This form was described as a new species, *B. intermedium* Iyengar in 1935 (see 4).

REVIEWS

WULFF, H. D.: Ein Vergleich zwischen Kultur—und Griffelpräparaten von Pollenschläuchen von *Narthecium ossifragum*. Beih. Bot. Centralbl. Abt. A. *54*, 83-98, 1935.

Recently it has been shown by several investigators (WULFF himself being one of them) that the division of the generative cell in the pollen tube shows the absence of several features described in ordinary mitosis. In this paper the author gives a comparative account of this division from a study of pollen tubes grown in culture and pollen tubes seen in longitudinal sections of previously pollinated styles. The results showed some remarkable differences.

In culture, the tubes are 5-7 times broader. The generative cell enters the tube in a state of early prophase, followed by a disappearance of the nuclear membrane. In the metaphase 13 chromosomes are seen arranged in a normal equatorial plate formed in the direction of the shorter diameter of the cell, and spindle fibres are clearly visible. The anaphasic movement of the daughter chromosomes is also quite normal and shows figures resembling ordinary mitosis. A division of the cell into two sperm cells does not occur by a phragmoplast or cell-plate, but by constriction.

Pollen tubes seen in sections of the style are much narrower; so that the generative cell occupies practically the entire width of the tube. Its nucleus continues to enlarge steadily from the early prophase to the anaphase. In metaphase the chromosomes are *not arranged in an equatorial plate* but form a row along the longitudinal axis of the nuclear space, and *spindle fibres are absent*.

The striking difference in the two cases seems to be related to a spatial factor, for tubes in the style are too narrow to permit the formation of a normal equatorial plate.

Wulff's work shows the need of great caution in the interpretation of the mechanism of division in the generative nucleus. Perhaps there will be cases where conditions in the style, as well as in pollen tubes grown on artificial media, will be found to be quite similar, but comparisons between the two will always be useful: in those plants, where the tubes are found to be appreciably broader in culture than in the style and show metaphases with equatorial plates and spindle fibres, a checking of the results by examining stylar sections is essential.

P. MAHESHWARI.

SAFIJOVSKA, L. D.: Spermatogenesis bei Campanulaceen. Bull. Sci. Univ. État de Kiev *1*, 265-278, 1935. (In Russian with German summary).

The author records here her earlier observations on *Adenophora liliifolia* Led. and adds an account of the development of the male

gametes in *Jasione montana* L., *Campanula persicifolia* L., *C. rotundifolia* L., *C. patula* L., and *C. cervicaria* L., as studied in artificial cultures of pollen tubes. In every case the pollen grains are two-nucleate at the time of shedding and the generative nucleus has its own cytoplasm which by its finer granulation and deeper staining is clearly distinguishable from the vegetative plasm. This corrects Mrs. Poddubnaja-Arnoldi's statement (1933) that the generative nucleus is naked in *Jasione montana.*

During the division of the generative cell, which occurs in the pollen tube, no spindle fibres are seen. Two sperm cells are formed, whose nuclei remain in a state of late telophase and are surrounded by a large amount of generative plasm. The elongated spindle-like shape of the generative cell, and the sperm cells formed from it, gives the impression that they have the power of active movement. The vegetative nucleus does not degenerate during the growth of the pollen tube.

The author thinks that these observations have a systematic value and that the whole family Campanulaceae is characterised by having two-nucleate pollen grains with the generative nucleus organised into a *cell.* This cell divides in the pollen tube and again gives rise to sperm cells (not mere nuclei).

H. D. Wulff (Kiel, Germany).

Fuchs, A.: Untersuchungen über den männlichen Gametophyten von *Eleagnus angustifolius.* Österr. Bot. Zeitschr. *85,* 1-16, 1936.

In this paper Miss Fuchs gives an exhaustive account of the development of the male gametes in *Eleagnus angustifolius.* The mature pollen grain is two-nucleate, containing a vegetative nucleus which could not always be seen clearly by the aceto-carmine method, and a deeply staining generative nucleus which is imbedded in a large amount of its own plasm. In cultures (1% agar + 10% sugar) the pollen grains showed a very good germination (almost 100%) and pollen tubes began to grow out 10 minutes after the grains had been sown on the substrate.

The generative cell is very small and does not occupy more than one-half of the diameter of the tube; sometimes it has a shape that suggests active movement. At the time of division of the nucleus it is seen lying close to the wall of the tube and seems to be attached to it by a tail-like projection of its plasm. The positions of the generative cell and the sperm cells vary greatly with regard to their distance from the tip of the pollen tube. It is the anaphases that were found at the greatest distance from the tip (up to about 14 times the breadth of the tube); metaphases were seen much nearer (at a distance of only 2-4 times the breadth of the tube). Sperm cells were seen from the same distance as the anaphases to as near the tip as the metaphases. This difference may be explained by

the fact that the pollen tube continues to grow, while the generative cell remains stationary during the interval of its division.

At the time of its first entry into the pollen tube, the chromosomes of the generative nucleus are arranged in two longitudinal rows, but later on a normal equatorial plate is formed which is oriented in a plane that is slightly oblique to the longitudinal axis of the cell. The anaphase is quite normal and of a short duration. Spindle fibres could not be observed, though the plasm gave the impression of a fine striation.

Neither a cell-plate nor a constriction could be seen during cytokinesis. It seems that the division of the plasm takes place by a wall formed at right angles to the longitudinal axis of the cell. The sperm cells contain a very appreciable quantity of plasm and are delimited by a membrane. The pair remain connected with each other for a long time—a fact described for some other plants also.

The occurrence of the cytoplasmic sheath round the generative as well as the sperm nuclei is noteworthy, but as regards details of the nuclear division itself the reviewer thinks it necessary to point out that Miss Fuchs has made all her observations only on pollen tubes that were grown in culture. As he has pointed out elsewhere (Beih. Bot. Centralbl. 1935) the conditions in the style are often not the same and a comparison of the two may show important differences.

H. D. WULFF (Kiel, Germany).

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